

**Lithologic Description
of the
Glenn's Ferry Formation
at
Hagerman Fossil Beds
National Monument,
Hagerman, Idaho**

Robert M. Lorkowski, 2002

**A report written for the National Park Service as
part of the Volunteers in the Park Program**

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Lithologic Description of the Glenn's Ferry Formation at Hagerman Fossil Beds National Monument, Hagerman, Idaho

Robert M. Lorkowski

Introduction

Purpose

This paper presents the results of a detailed study of the lithology of the Glenn's Ferry Formation that is exposed in outcrop within the boundaries of Hagerman Fossil Beds National Monument, in Twin Falls County, west of Hagerman, Idaho. Previous researchers have described the Glenn's Ferry Formation as a clastic fluvial-lacustrine depositional system. The purpose of this paper is to supplement previous work with a more detailed description of the lithologic units.

A two tiered hierarchical approach should be taken when the resources of a sedimentary basin are being explored, (Galloway and Hobday, 1996). First, a general picture of the architecture of the basin should be determined and the major packages of sediments described. Previous researchers have accomplished this task. The second stage involves detailed descriptions of lithologically defined sedimentary units. Presented are detailed lithologic descriptions about individual sedimentary units of the Glenn's Ferry Formation at Hagerman Fossil Beds National Monument. They have been grouped into sedimentary facies in an effort to provide an additional tool for the National Park Service to use in managing the prolific Pliocene fossil resources found in the Glenn's Ferry Formation.

Location

Hagerman Fossil Beds National Monument is located in Southern Idaho near the town of Hagerman, Idaho (Figure 1). Hagerman is located approximately 30 miles west of Twin Falls Idaho, on U.S. Highway 30. The monument headquarters and the Research Center are located in the town of Hagerman. The fossil beds are exposed in 600-foot high bluffs on the western side of the Snake River, across from the town of Hagerman (Figure 2). Collection of fossils by the general public are not permitted, however, researchers may gain access by applying to the National Monument for permits. The bluffs are accessible from the mesa at the top of the bluffs and the bottom is accessible by boat from the Snake River (Figure 3). A paved road provides access to the farming area on the plateau above the bluffs and dirt farm roads provide access to several locations on the edge of the bluffs.

Previous Work

The Glenn's Ferry Formation has been described as a sand body that was deposited in the Pliocene Epoch of the Cenozoic Era (Cope, 1884, Malde and Powers, 1962). The Glenn's Ferry Formation has been traced over a large part of Southwestern Idaho and parts of Oregon (Malde and Powers, 1962 and Kimmel, 1975). The formation is considered to be part of the Western Snake River Plain geomorphic province (Swirydczuk, 1982). The Glenn's Ferry Formation is part of the Idaho Group (Figure 4), which consist of clastic beds and intercalated basalt flows of Miocene to Pleistocene age (Malde and Powers, 1962). Fossils found in the Glenn's Ferry Formation are primarily from the Blancan era (Malde and Powers, 1962), with the most important fossil beds existing on the hill sides above the Snake River near Hagerman, Idaho, which are now included in the Hagerman Fossil Beds National Monument

In the course of describing many of the fossil faunas found at Hagerman, Philip R. Bjork (1970) studied the stratigraphy of the Glenn's Ferry Formation. A total of eight stratigraphic sections were measured and described. Two of the sections were in Hagerman Fossil Beds National Monument. Bjork described a fluvial and lacustrine environment with the lacustrine portion resting on the Banbury Basalt. He described the sands in Peter's Gulch as being deposited in a broad flat plain with shallow water, based, in part on ripple marks found in the Peter's Gulch Ash. Above these units he described a diatomaceous silt and shale, which represented a slack water environment. Bivalves found in channels above the diatomaceous shales were used to identify river mouths. Back swamps were also observed in his measured sections. These observations led to a conclusion that the deposits were in proximity to a large fresh water lake, now referred as the Pliocene Lake Idaho. He inferred that that the vertical sequence of facies was caused by a subsiding basin.

Malde (1972) published geologic maps of the Glenn's Ferry-Hagerman area that showed the distribution of the Glenn's Ferry Formation. Previous maps were reconnaissance in nature (Lindgren, 1900; Russell, 1902, Malde and Powers, 1962). Malde (1972) studied the Glenn's Ferry Formation between Hammett and Hagerman, Idaho. He recognized a lateral relationship between three facies, flood plain silts, fluvial sands, and lacustrine silts. He interpreted the depositional setting as a broad valley, a river, temporary lakes, and areas that were seasonally flooded.

Volcanic ashes have been used to establish geological time frames and correlate rock units within the Glenn's Ferry Formation. Powers and Malde (1961) proposed two volcanic ash beds as stratigraphic markers to correlate units in the Glenn's Ferry-Hagerman area. One of these units was the Peter's Gulch Ash, which they traced over a distance of 20 miles. Swirydczuk and others (1982) conducted studies of the stratigraphy of the Glenn's Ferry Formation in Owyhee County using volcanic ashes. Hart (1999) recently refined many ages of the volcanic ashes in Hagerman Fossil Beds National Monument.

Smith and others (1982) interpreted the Glenn's Ferry Formation as a lacustrine-fluvial floodplain environment based on the vertical distribution of fish fossils. Beach facies and river mouths were identified through the existence of

critical species. Transgressive beach facies, shore facies, offshore silts, and flood plain silts were identified in the study. Part of the fluvial facies identified by Malde and Powers (1962) were redefined as shore facies. The flood plain sequence at Hagerman is represented mostly by lakebeds in western exposures of the Glenn's Ferry Formation according to their study. They concluded that Hagerman deposits are older than beds found in the west and the upper section at Hagerman is time equivalent to lacustrine beds in Owyhee County.

Kimmel (1982) determined that lacustrine sediments of the Glenn's Ferry Formation were deposited in a large, permanent lake. The study also recognizes regressive beach sands in the Glenn's Ferry Formation. Kimmel studied fish fossils to make this determination. Large lake fluctuations were used to explain the regressive sequences. Kimmel also strongly argued against Malde's interpretation (1972) of the sediments being deposited in a wide valley, with a river, temporary lakes, and areas that were seasonally flooded.

Swirydzuk and Larson (1982) conducted studies on volcanic ash layers in the Glenn's Ferry Formation and the Chalk Hills Formation. The ash layers were used to correlate stratigraphic sections in the Twentymile Gulch, Shoofly Creek, Horse Hill, Upper Poison Creek, Crayfish Hill, Picket Creek and Fossil Creek areas in Owyhee County. An oolitic limestone deposit was used to establish the base of the Glenn's Ferry Formation. They came to the conclusion that ash layers have limited use in correlating units in the Hagerman bluffs.

As a volunteer while working at Hagerman Fossil Beds National Monument, Harrington-Thornton, H. (1984) measured and described a lithologic column. The column was located in what is now a very hazardous land slide area. This information is included in this report as it provides information, which can not be obtained in a safe manner today.

Repenning and others (1995) conducted a regional study using marsh deposits to assist in correlating Miocene and Pliocene units in Oregon and southwest Idaho. They identify the primary fluvial system at the time as the Snake River. The shores of a large lake, Lake Idaho, existed mainly to the north and the west of Hagerman Fossil Beds National Monument. They reasoned that a westerly flowing Snake River deposited the Hagerman sediments as it entered Lake Idaho at this location. They discussed the time relationship of the Glenn's Ferry Formation at Hagerman with outcrops to the west, showing that the Hagerman deposits were older. They used the marshy deposits exposed in the bluffs of Hagerman as part of their study.

Dana E. Lee (1995) expanded on Bjork's work (1970). Lee conducted a study of the sedimentologic factors influencing landslides in Hagerman Fossil Beds National Monument. Lee measured three additional stratigraphic sections and correlated his work with Bjork's measured sections. Lee concluded that the deposits were marginal and westward of Lake Idaho. Paleocurrents investigated by Lee showed a wide variance and suggested that a sinuous meander belt existed.

Lee (1995) recognized three members of the Glenn's Ferry Formation in a vertical sequence, which were delineated by two major volcanic ash units. The Lower Member existed below the Peter's Gulch Ash. Lee believed that the clays

and silts in the Lower Member were lacustrine deposits and referred to them as a muddy association. He believed that perhaps earlier researchers failed to note the clays as lacustrine because they believed that the clays were part of the Yahoo Clay. The Middle Member was defined as the units between the Peter's Gulch Ash and the Fossil Gulch Ash. The Upper Member included units above the Fossil Gulch Ash, which he referred to as the Sandy Association.

W. K. Hart (1999) analyzed and dated volcanic horizons in the Glenn's Ferry Formation at Hagerman Fossil Beds National Monument. And adjacent areas. 40 Ar/39 Ar dates were compared with the Geomagnetic Time Scale. Ages of basalt exposed at the bottom of the Glenn's Ferry Formation, which are thought to be the Banbury Basalt range from 4.29 Ma to 4.18 Ma. The Horse Quarry ash was determined to be 3.2 Ma. An unconformity was recognized in the stratigraphic vicinity of the Shoestring Basalt, approximately 100 feet below the Horse Quarry. Dating of the nearby Deer Gulch Basalt indicates a period of approximately .25 Ma for this unconformity. Depositional rates for the sediments below the Shoestring Basalt are estimated to be between 0.16 mm/yr. and 0.21 mm/yr. Sediments above the Shoestring Basalt were deposited at a rate of 0.46 mm/yr., which includes the sediments deposited in the vicinity of the Horse Quarry.

Method of study

In this study, four lithologic columns were measured and described in the outcrops exposed in the bluffs above the Snake River within the boundaries of Hagerman Fossil Beds National Monument (Figures 5). Of these four columns, only two are reasonable representations of river to rim sections. The bottoms of all four sections are covered by landslide material, which are common in the monument. From South to North, these are known as the Peter's Gulch Section, Section 21 Section, the Fossil Quarry Section, and the Bald Knob Section (Figures 6,7,8, and 9). Trenches were dug through the overburden to expose the lithologic units. Units as thin as one inch were described in the field. Samples from these units were gathered and examined microscopically to provide a petrologic description.

Field observations were made using limited exposures in trenches, as deep as one foot and usually only six inches wide. Thick colluvium covers most of the slopes making direct observations of the units extremely difficult. Interpretation of changes in slope, features indicating resistance to erosion, and changes in vegetation were used to determine the lateral extent of the units and bed forms Fossils and minerals were also identified in the field.

Sand samples from each lithologic unit were examined under a microscope. Grain size, sorting, roundness, cement, and minerals content were determined for each unit (Appendix 1-4). Color was determined using a Munsell Rock Color Chart. Microscopic fossils were also identified. Samples of the lithologic units are available for inspection at the Hagerman Fossil Beds National Monument Research Facilities.

The thickness of the lithologic units were entered into a database and processed using Rock Ware software. Illustrations of the four lithologic columns were prepared by processing data in the Rock Ware computer program (Figures 6,7,8, and 9). An illustration of a fifth column (Figure 10) was prepared from data in a report written for the National Park Service by H. Harrington-Thornton (1984). The Harrington-B column is located in a present day landslide area which is too hazardous for field work.

Subfacies of the Glenn's Ferry Formation at Hagerman Fossil Beds National Monument are identified in this study. Elevations for the upper and lower boundaries of these subfacies were determined from the lithologic columns and a cross section and a projected cross section were prepared using the Rock Ware computer program (Figure 11 and 12). Lithologic columns prepared by previous researchers (Malde and Powers, 1962; Bjork, 1970; Lee, 1995; Harrington-Thornton, 1984) were examined and the upper and lower limit of the subfacies was interpreted from their work and added to the cross sections.

Observations

Five clastic depositional facies within a fluvial-lacustrine system were identified. An off shore, nearshore, shoreline, flood plain and stacked channel facies in the Glenn's Ferry Formation at Hagerman Fossil Beds National Monument (Figure 11 and 12) are described in this study.

Off-Shore Facies

Massive tabular clay deposits characterize the Off Shore Facies. The clay deposits can best be seen in the lower portion of the Peter's Gulch Lithologic Column, Units 1-15 (Figure 6 & 13). These units are also exposed along the shore of the Snake River (Figure 14). These units appear to be green and gray along the river. In the interior areas the units have been oxidized and appear as pale brown silty clays. However, trenching to a depth of approximately two feet reveals the green hues seen along the bluffs by the river. These clays are massive and tabular. There is no evidence to suggest that the clays were deposited in deep water. Clam shell as large as 4 inches have been found in these clays. The clays representing the Off Shore Facies are also exposed in the lower portion of the Section 21 column, Units ? to ? (Figures 7).

The lithologic units, which are here being described as the Off Shore Facies, are believed to be the same units that Lee (1995) described as lacustrine units deposits. He stated that these units were probably misinterpreted by previous researchers as being part of the Pleistocene Yahoo Clay. This author investigated deposits of the Yahoo Clay in the vicinity of Hagerman Idaho (Lorkowski & Riggins, 1998). The Yahoo clays were found to have been deposited in an angular unconformity with units of the Glenn's Ferry Formation. The relationship between the two formations can be clearly seen in the southern part of the monument (T. 8 S., Sec.4). The Yahoo Clay can be distinguished from the clay in units of the Glenn's Ferry Formation by its light yellowish color and fissile nature.

Nearshore Facies

Channels in predominantly silty deposits characterize the Nearshore Facies. The lower part of this facies is marked by the first occurrence of these channels (Figure 15). The channels at the very bottom are only a few inches wide. Channels that are tens of feet wide occur within thirty feet higher stratigraphically. This facies can be identified in all four of the lithologic columns examined in this study. They include lithologic units 16-58 in the Peter's Gulch column (Figure 6), units 104 -151 in the Section 21 column (Figure 7), units 146-152 in the Fossil Canyon column (Figure 8) and units 96-169 in the Bald Knob column (Figure 9). The occurrence of shell hash, clamshells, and an abundance of gypsum in the units indicate a subaqueous environment. Organic rich muds and clays occur at the top of this facies.

The bottom of the nearshore facies is delineated by the first appearance of channels, which can only be seen in the Peter's Gulch column (Figure 15). These channels increase from a few inches wide at the bottom to tens of feet in width. Clamshells and shell hash are abundant in these channels. Ripple marks have been preserved on the surface of the Peter's Gulch Ash, which can be found in the lower part of the facies. The channel sands are interpreted as channel sands deposited in subaqueous distributary channels. Tabular bodies of fine sand that grade upward to silts are found in the upper part of this facies are interpreted as having been deposited in distributary channel mouth bars.

The Peter's Gulch Ash is a rhyolitic ash, which can be found in most parts of the National Monument. It is stratigraphically located in the lower portion of the Near Shore Facies. In the Peter's Gulch Lithologic Column (Figure 6) the unit is found within a channel sand deposit (Units 24 & 25, Figures 15). The outcrop of the ash adjacent to the channel has a rippled surface (Figure 14). The ripples can be observed in outcrops of the Peter's Gulch Ash in the Section 21 Lithologic Column (Figure 7, Unit 12) and at many other locations in the monument. The sands and clays immediately below the ash contain clamshells. This evidence indicates that the Peter's Gulch Ash was deposited in shallow water, as described by Bjork (1970).

Repetitive sequences of brown and olive green carbonaceous clays covered by fine silts deposits in the upper portion of the Near Shore Facies suggests occasional subaerial exposure indicating periodic lake level fluctuations. A fossil peccary was discovered in one of the layers of carbonaceous clay. The layers of silt appear to be deposited in an aeolian environment. The evidence suggests that the carbonaceous clay units were deposited adjacent to the shoreline of a paleolake in very shallow water.

Shoreline Facies

Reddish brown diatomaceous shales characterize the Shoreline Facies (Figure 18). The shales are known locally as the "Paper Shales". The name of the unit refers to a paper-like quality exhibited by weathered portions of the unit, in the fact that it is light weight, can be broken up into fine sheets and remains

coherent if it is handled carefully. The weathered portions break up into a very fine powder when it is crushed by hand. Carbonaceous leaf prints resembling reeds can be found between the sheets of the Paper Shales. Fossil root casts have been found in the unit. The shale appears to be primarily composed of diatoms. The unweathered portion of the unit is a very competent clay-like material that serves as an aquatard to the local groundwater flow. The units have been investigated and surveyed (Lorkowski and Hauser, 1996) and are believed to be continuous at approximately at the 3100 foot elevation in the vicinity of the monument and to the north of the monument. For this reason the units are considered to be fairly reliable marker beds in the study area.

Stream channels of all sizes can be recognized in the facies. A fossil Giant Beaver was recovered from one of the larger channels. Repetitive sequences of a light olive green clay, dusky yellowish brown clay and a layer of the diatomaceous shale suggests fluctuating lake levels at the time of deposition. The units in the shoreline facies are represented in the Peter's Gulch column as units 64-78 (Figure 6), in the Section 21 column as units 69 - 103 (Figure 7), in the Fossil Gulch column as units 136 – 146 (Figure 8), and in the Bald Knob column as units 86-102 (Figure 9). A black basaltic ash layer can be found in most sections near the top of the facies or a few feet above the facies. This basaltic ash has been radiometrically dated at 3.2 M A. (Hart, 1999). The depositional environment is interpreted to be a marsh, which can be commonly, found in the vicinity of a lakeshore where streams enter the lake.

Flood Plain Facies

Units interpreted by this author and previous authors as Point Bar deposits, Stream Channels, Channel Levee deposits, and Back Swamps characterize the Floodplain Facies. The Facies can be identified in every lithological section measured in the study area. The historic Horse Quarry, where skeletons of approximately 125 individual equine specimens were recovered, is located in this facies (Figure 18). The units are represented in the Peter's Gulch column as units 17 – 63 (Figure 6), in the Section 21 column as units 3 - 68 (Figure 7), in the Fossil Gulch column as units 3 - 135 (Figure 8), and in the Bald Knob column as units 61-85 (Figure 9). Sand grain sizes from clay to fine sand are found in the facies. Medium grained sands and larger are found only in relatively few channel deposits. Diatomaceous shale deposits stratigraphically above the Shoreline Facies in the Peter's Gulch and the Section 21 columns have been interpreted to be back swamp or shorelines of small lakes in the flood plain.

Three types of channels can be found in the Floodplain Facies. The geomorphic and sedimentary descriptions of the channels are from Galloway and Hobday (1996). Suspended load channels, Mixed load channels and bedload channels can be identified in each of the sections measured. The suspended load channels are characterized by a dominantly silt and mud composition and a very low width to depth ratio. The sequence of sedimentary deposits is usually obscure due to the abundance of fine material. Lateral relationships of the

channels are characterized by multistory channel fills in abundant overbank mud and clay. Bank accretion dominates sediment infill. Suspended load channels can be seen in map view as highly sinuous to anastomosing streams. Examples of this type of channel in the Peter's Gulch column can be seen in units 52 to 54 (Figure 6), in the Fossil Gulch column as units 82 to 87 and in the Bald Knob column in units 73 and 74 (Figure 9).

Mixed Load channels are described by Galloway and Hobday (1996) as being composed of mixed sand, silt and mud with moderate width to depth ratios. Sediments in these channels fine upward. Bank and bed accretion are both preserved in the sediment infill. In a lateral view multistory channels are subordinate to the overbank deposits (Figure 19). Streams with this type of channel can be seen in map view as being sinuous. Examples of this type of channel in the Peter's Gulch column can be seen in units 28 and 29 (Figure 6, and 19), in the Fossil Gulch column as units 82 to 87 (Figure 8), and in the Bald Knob column in units 52 to 54 (Figure 9).

The third type of channel that can be identified in the lithology of the Glenn's Ferry Formation is the Bedload Channel. These channels are dominantly sand channels with high width to depth ratios. Bed accretion dominates the sediment infill. The fining upward sequence is irregular and poorly developed. Channel fills commonly exceed overbank deposits in lateral relations. In map view these streams are straight to slightly sinuous. The channel being excavated in the Horse Quarry (Figure 20). Examples of this type of channel in the Peter's Gulch column can be seen in units 7 to 16 (Figure 6 and 21), in the Fossil Gulch column in unit 27 (Figure 8), and in the Bald Knob column in units 56 to 58 (Figure 9).

Although the three types of channels can be seen at all stratigraphic levels in the Flood Plain Facies, observations indicate that the lower half of the facies has more suspended load channels and mixed load channels than the upper half which contains more bedload channels.

A large number of tabular sand and silt units can be found in the Flood Plain Facies. These units can be interpreted as either Point Bar deposits or sheet flow deposits. Poor exposures make interpretations of these units very difficult. Sedimentary structures are poorly preserved in the weathered material.

Stacked Channel Facies

A thick sequence of stacked channels was encountered in the Peter's Gulch column, (Figure 21). The channels are stratigraphically above the flood Plain Facies, units 7 to 16 (Figure 6). The Horse Quarry is on the same stratigraphic level as the Peter's Gulch column. These bedload channels represent major stream channels.

The channels are a series of bedload channels stacked on top of each other. The Peter's Gulch units are 104 feet thick. Individual channels can be as thick as 27 feet. Grain sizes vary from coarse sand to silt and fine upward in individual channels. The general direction of flow appears to be in an East-West direction, based on the geometry of the smiles of the channels.

Conclusions

Sediments in the Glenn's Ferry Formation that are exposed in Hagerman Fossil Beds National Monument were deposited in a prograding delta system that developed in a shallow fresh water lake. Repenning and others (1995) proposed that the Snake River provided the sediments for the Glenn's Ferry Formation in the study area. The shallow water lake was the prehistoric Lake Idaho, which covered most of southwestern Idaho and a portion of eastern Oregon. The northern and eastern limits of the lake were in the vicinity of King Hill, which is to the north of the study area. Malde (1972) suggested a transition between fluvial and lacustrine sediments from this study area northward to the vicinity of King Hill. The results of this study provides further evidence supporting Malde's and Repenning's observations.

Deltas are areas where rivers empty into bodies of water causing a bulge in the shoreline (Galloway and Hobday, 1996). Subaqueous and subaerial sediments are included in the deltaic sediment package. The five facies of the Glenn's Ferry Formation identified in this study, the Off Shore, Nearshore, Shoreline, Flood Plain, and the Stacked Channel facies, correspond with the prodelta, distributary channels, shoreline marshes, alluvial plain and main channel facies found in deltas. Very fine sediments similar to the sediments of the prodelta deposits are found in the Off Shore Facies. Green hues in exposed clay units of the Off Shore Facies attest to subaqueous deposition and an anoxic environment. Channel deposits and tabular deposits that fine upward, similar to sediments in channel mouth bars, are found in the Nearshore Facies, very much like the distributary channels of a delta. Repetitive sequences of brown mud covered by units of silt suggest fluctuating lake levels. Reed like fossils found in the carbonaceous shales of the Shoreline Facies are similar to those found in marsh areas of deltas. Fluvial deposits and stacked channel deposits found in the study area are consistent with fluvial deposits of a delta. Evidence supports the concept of a deltaic environment at Hagerman Fossil Beds National Monument.

The vertical sequence of sediments at Hagerman indicates progradation of the sedimentary package into Lake Idaho. The Snake River probably flowed in a westerly direction (Repenning and others, 1995) accounting for the younger dates obtained for the Glenn's Ferry Formation to the west of Hagerman. The lobate nature of a delta system accounts for the discontinuity of the sedimentary units in the study area. A delta system would provide an ideal environment for the abundance of fauna found at Hagerman.

The approximately 630 foot thickness of the Glenn's Ferry Formation at Hagerman, the low dip angles, 1-4°, of the sedimentary units, and the lack of a clear regional unconformity within the Glenn's Ferry Formation suggests the possibility that the surface of the fan delta in the Hagerman region was usually close to horizontal. Hart (1999) determined sedimentation rates between 0.07 mm/yr. and 0.46 mm/yr. For the deposits to remain nearly horizontal then the subsidence rate of the basin must have been equal to the sedimentation rate.

The clastic sediments in the Glenn's Ferry Formation which are exposed in the bluffs of Hagerman Fossil Beds National Monument represent the interface of Malde's (1972) fluvial system and the large regional lake, Lake Idaho, proposed by Kimmel (1982).



Figure 2.

View of the Glenn's Ferry Formation exposed in the cliffs of Hagerman Fossil Beds National Monument



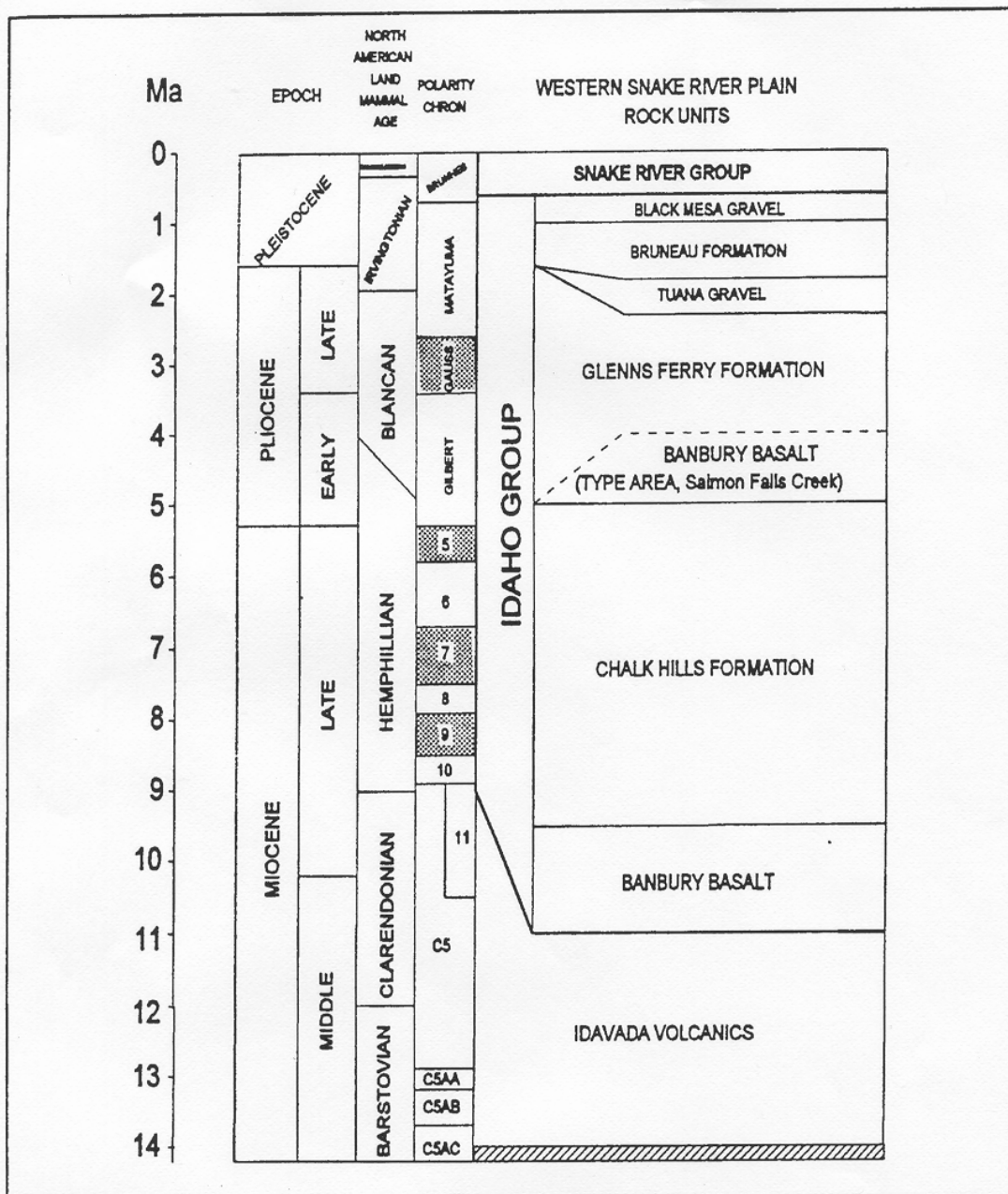


Figure 4.

**Stratigraphic correlation chart for Cenozoic rocks in the
Southwestern part of the Snake River Plain
(Modified from Malde, 1972)**

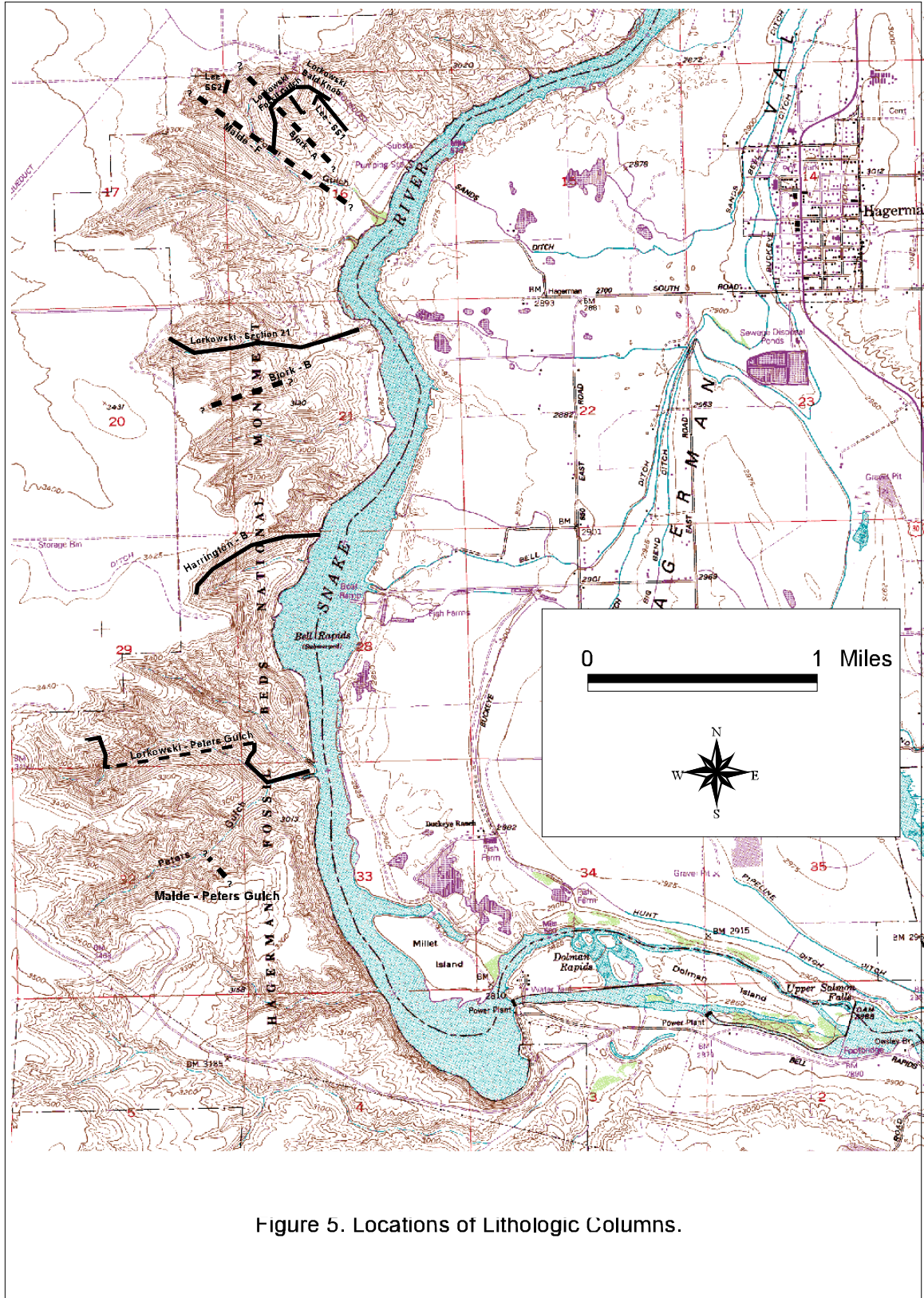


Figure 5. Locations of Lithologic Columns.

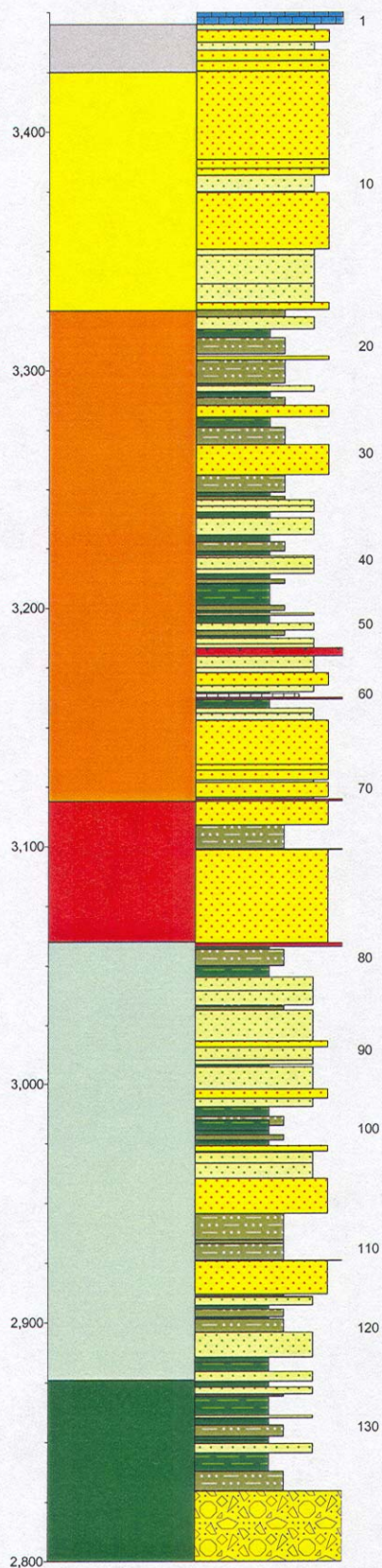


Figure 6
Peters Gulch Lithologic Column



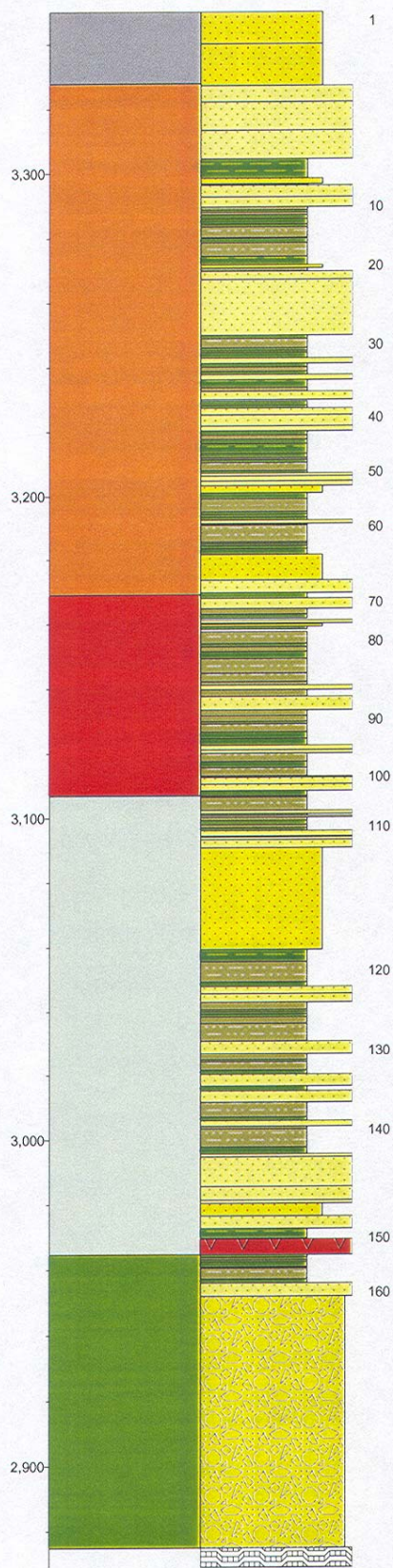


Figure 7.
Section 21 Lithologic Column



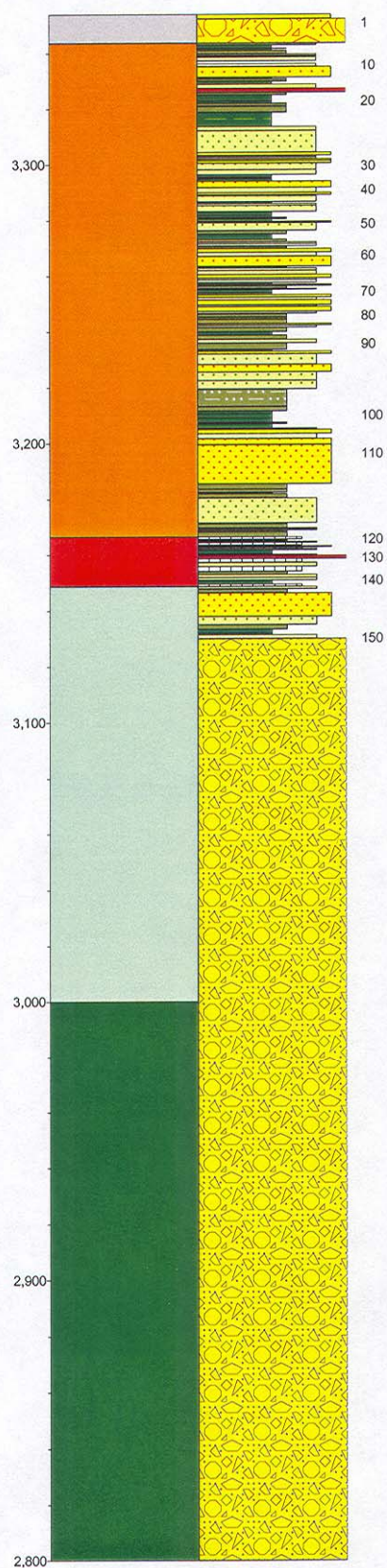


Figure 8.
Fossil Gulch Lithologic Column



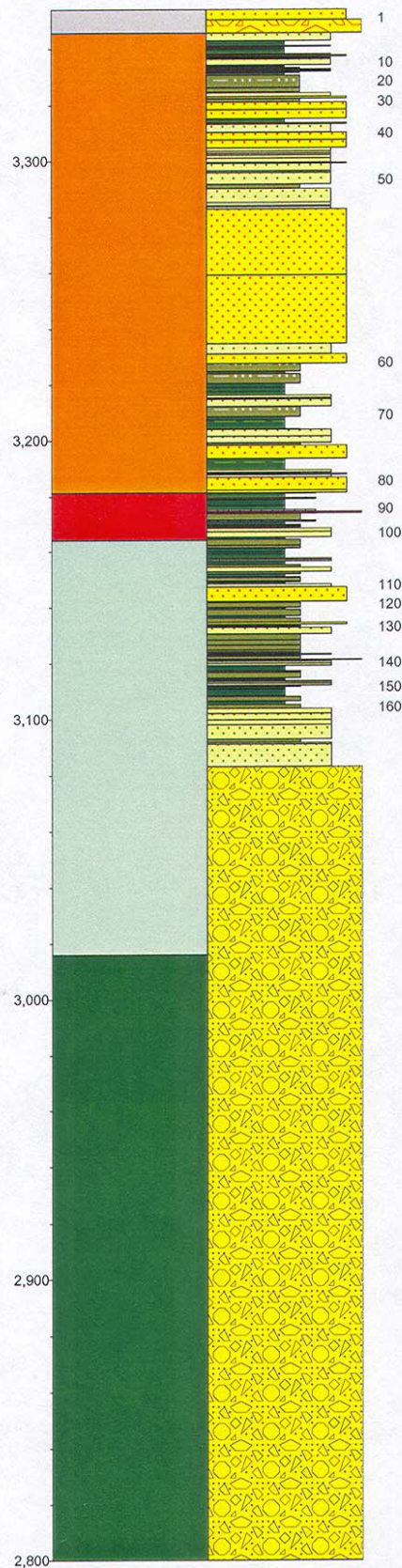
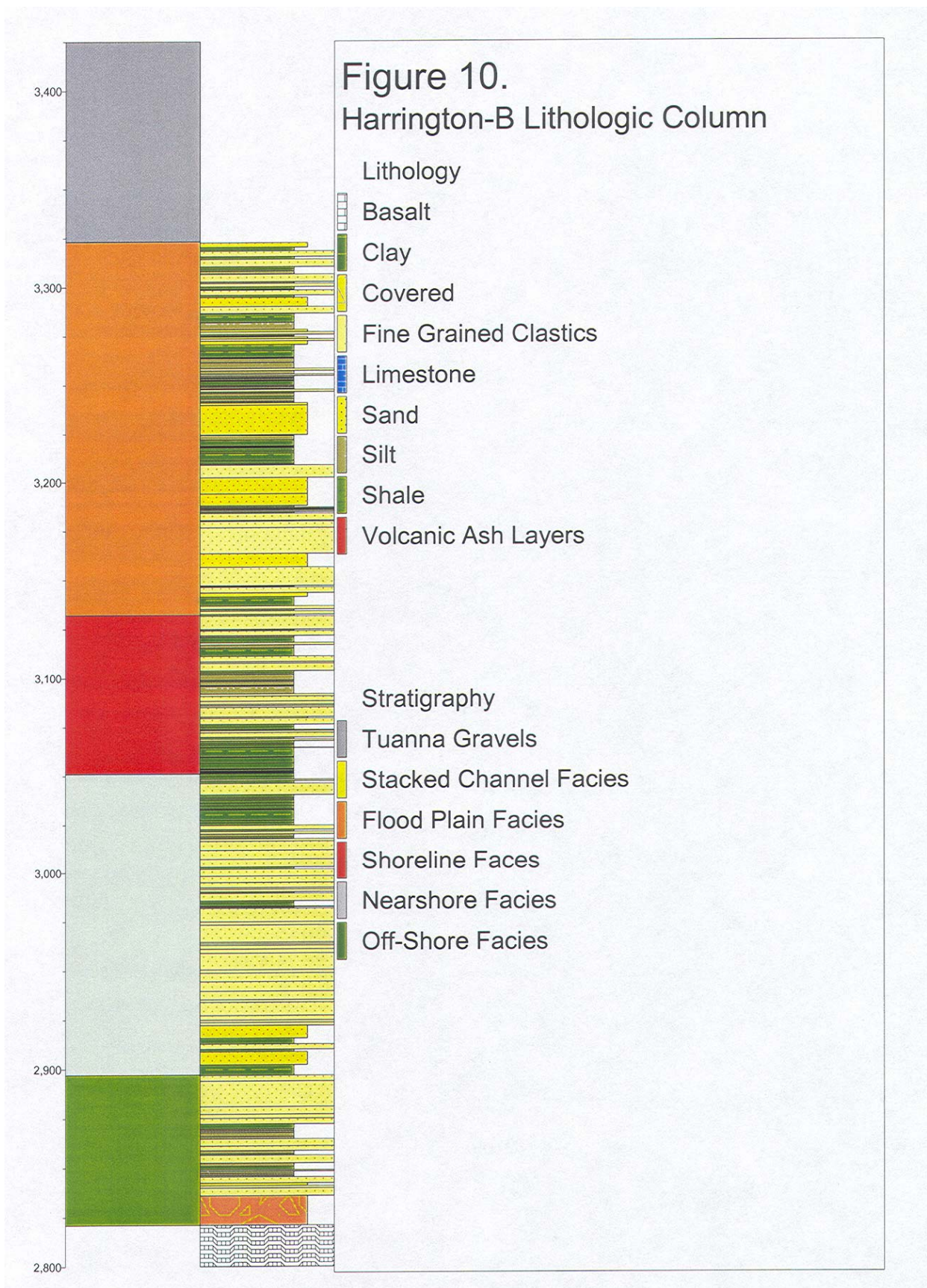


Figure 9.
Bald Knob Lithologic Column





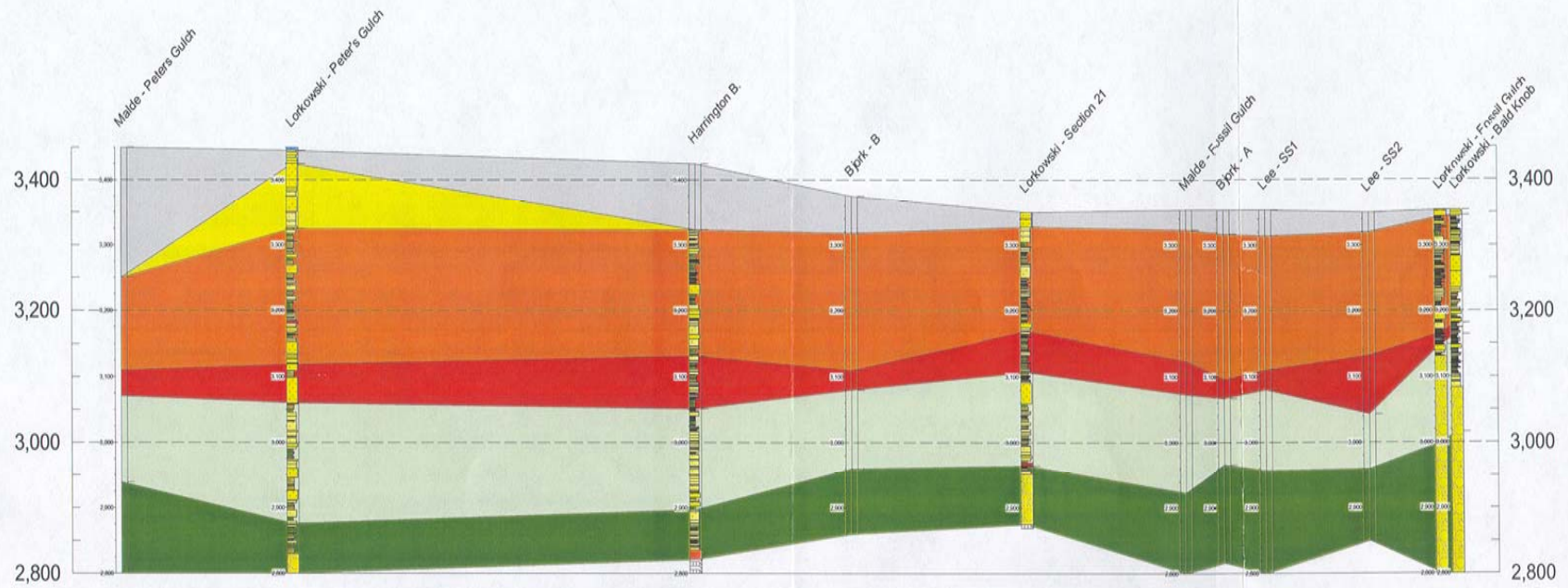


Figure 11.

Cross Section of Glens Ferry Formation



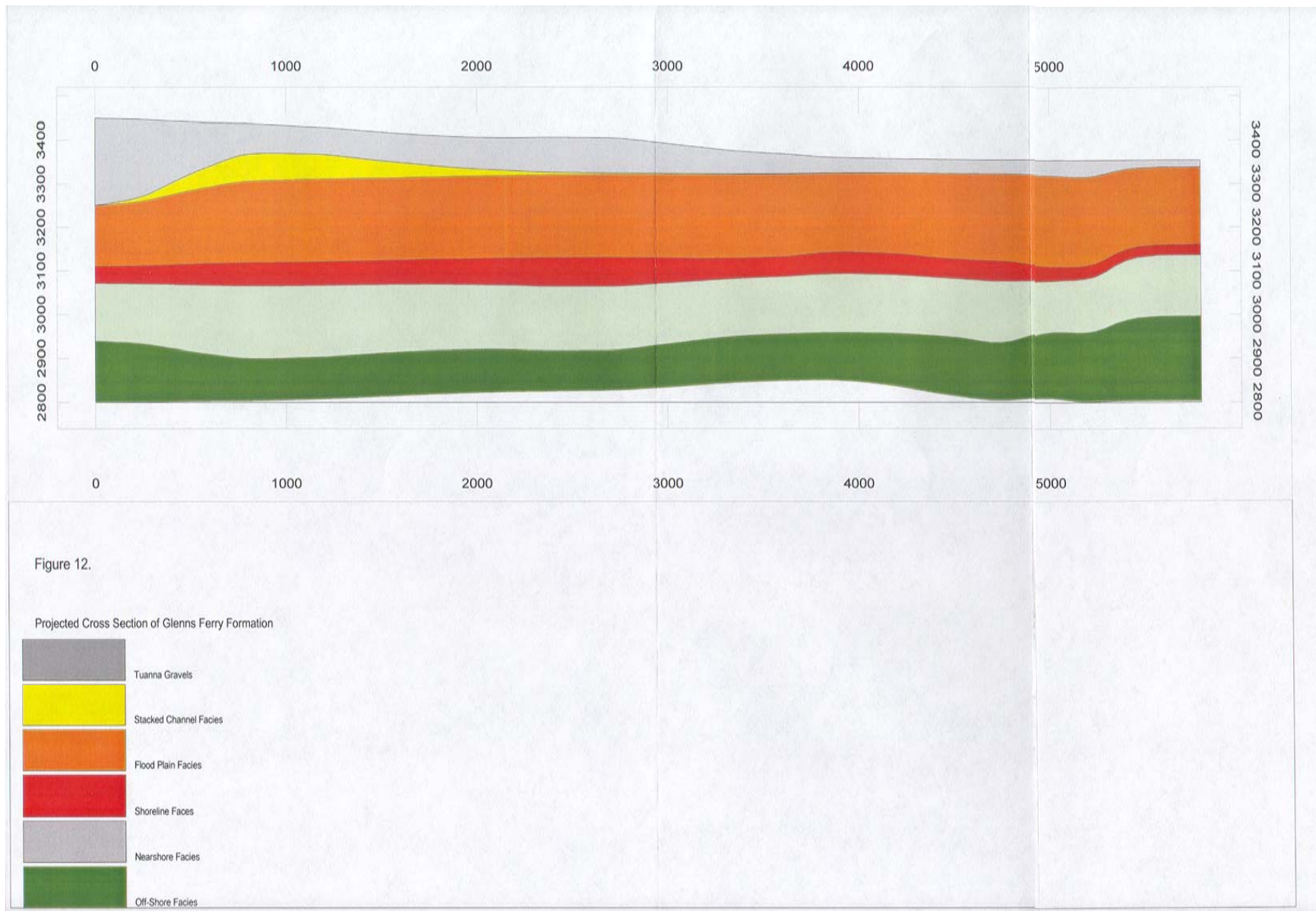




Figure 13.

Off-Shore Facies exposed in the Peter's Gulch
Lithologic Column.



Figure 14.

Off shore Facies exposed along the Snake River.



Figure 15.

Small channels at the bottom of the Nearshore Facies
Exposed in the Peter's Gulch Lithologic Column.



Figure 16.

Peter's Gulch Ash exposed in the
Peter's Gulch Lithologic Column.



Figure 17.

Ripple marks on the surface of the Peter's Gulch Ash
In the Peter's Gulch Lithologic Column.



Figure 18.

Diatomaceous Shales that characterize the Shoreline Facies.



Figure 19.

Levees of a mixed load channel in the Peter's Gulch Column.



Figure 20.

Bed load channel in the Flood Plain Facies known as the Horse Quarry.



Figure 21.

Stacked Channel sequence in the Peter's Gulch column.

APPENDIX A

PETROGRAPHIC DESCRIPTIONS

Peter's Gulch Lithologic Column

Top of Column

- 1 White limestone, **5 feet thick, oolitic, channel fill in lower portion, contains pebbles supported by the ooids, pebbles are rounded basalt and quartzite.**
- 2 Pale yellowish brown (10YR 6/2) fine sandstone, **2 feet 5 inches thick, tabular, moderately consolidated, massive, well sorted subangular quartz, lithic particles, citrine, calcite cement, ¼ inch calcite nodules, covered by colluvial deposits.**
- 3 Pale yellowish brown (10YR 6/2) medium sandstone, **5 feet 0 inches thick, tabular, very well consolidated, massive, moderately sorted, angular quartz, lithic particles, volcanic glass, yellow coating on grains, calcite cement, covered by colluvial deposits.**
- 4 Pale yellowish brown (10YR 6/2) fine sandstone, **3 feet 1 inch thick, tabular, poorly consolidated, massive, moderately sorted, subangular quartz, black lithic particles, biotite, small plates of calcite, calcite cement, covered by colluvial deposits.**
- 5 Pale yellowish brown (10YR 6/2) fine pebbly sandstone, **4 feet 6 inches thick, tabular, slightly consolidated, massive, matrix supported, very poorly sorted, subangular quartz, lithic particles, calcite cement. Pebbles are volcanic, plutonic, and metamorphic. The unit correlates with the Tuanna Gravels found in other portions of the monument. Colluvial deposits cover the unit.**
- 6 Pale yellowish brown (10 YR 6/2) pebbly sandstone, **4 feet 3 inches thick, tabular, slightly consolidated, massive, moderately sorted, rounded quartz, feldspar, lithic particles, hornblende, biotite, calcite cement, covered by colluvial deposits and vegetation.**
- 7 Yellowish gray (5YR 8/1) coarse sandstone, **37 feet 0 inches thick, stacks of channel deposits (at least 4 identified) unconsolidated, massive, well sorted, rounded, quartz, biotite, black lithic particles, calcite cement, blow out.**
- 8 Pinkish gray (5YR 8/1) coarse sandstone, **3 feet 9 inches thick, tabular, well consolidated, massive, well sorted, rounded quartz, black lithic particles, biotite, feldspars, calcite cement, covered by colluvial deposits.**
- 9 Very pale orange (10YR 8/2) medium sandstone, **2 feet 10 inches thick, tabular, well consolidated, massive, moderately sorted, rounded quartz, biotite, black lithic particles, well cemented with calcite, forms steep slopes.**
- 10 Light brownish gray (5YR 6/1) fine sandstone, **6 feet 10 inches thick, channel deposit, lenticular, 100 feet wide, unconsolidated, massive, well sorted, subrounded quartz, lithic particles, hornblende, feldspar, biotite, blow out.**
- 11 Grayish orange pink (5YR 7/2) fine sandstone, **1 foot 2 inches thick, top of channel in unit #143, moderately consolidated, massive, moderately sorted, subrounded, quartz, biotite, black lithic particles, calcite cement, covered by colluvial deposits.**

- 12 Light brownish gray (5YR 6/1) medium sandstone, **24 feet 2 inches thick, channel deposit, 70 feet wide, unconsolidated, moderately sorted, rounded, quartz, volcanic glass, muscovite, biotite, calcite cement. Coarser grains evident in anthills. Some areas are well cemented. Unit is covered by vegetation.**
- 13 Yellowish gray (5Y 8/1) very fine sandstone, **2 feet 5 inches thick, tabular, very well consolidated, some evidence of flow structure and channel fill, well sorted, angular quartz, feldspar, hornblende, citrine, clast supported, calcite cement. Creates 45o slope, 100-foot lateral exposure, exposed on many other ridges within ½ mile distance.**
- 14 Pale yellowish brown (10YR 6/2) fine sandstone, **12 feet 0 inches thick, channel deposit, lenticular, 120 feet wide, unconsolidated, blow out, poorly sorted, rounded quartz, feldspar, biotite, hornblende, calcite cement. Contains calcite cemented sand nodules average ½ inch diameter with larger 8 x 4 x 2-inch nodules in the unit.**
- 15 Pale yellowish brown (10YR 6/2) fine sandstone, **8 feet 0 inches thick, tabular, slightly consolidated, massive, well sorted, subrounded quartz, biotite, calcite cement, forms steep slopes.**
- 16 Grayish brown (5YR 3/2) coarse sandstone, **3 feet 0 inches thick, channel deposit, lenticular, 15 feet wide, outlined by vegetation, moderately sorted, subrounded quartz, black lithic particles, volcanic glass, biotite, apatite, calcite cement, contains calcite cemented sand nodules, covered by colluvial deposits.**
- 17 Pale yellowish brown (10YR 6/2) silt, **3 feet 0 inches thick, tabular, moderately consolidated, massive, well sorted angular quartz, calcite cement, forms steep slopes, covered by colluvial deposits.**
- 18 Pale yellowish brown (10YR 6/2) very fine sandstone, **4 feet 8 inches thick, tabular, unconsolidated, massive, well sorted, angular quartz, lithic particles, calcite cement. Contains many calcite cemented sandstone nodules that average 1 foot x 3 inches x 8 inches. Approximately 70-foot exposure to the west, covered by colluvial deposits to the east.**
- 19 Dark yellowish brown (10YR 4/2) clay, **4 feet 0 inches thick, tabular, well consolidated, massive, carbonaceous organic material, covered by colluvial deposits.**
- 20 Pale yellowish brown (10YR 6/2) silt, **7 feet 1 inch thick, tabular, slightly consolidated, massive, well sorted, angular quartz, biotite, covered by colluvial deposits.**
- 21 Pale yellowish brown (10YR 6/2) medium sandstone, **2 feet 5 inches, tabular, moderately consolidated, massive, poorly sorted, rounded quartz, biotite, black lithic particles, calcite cement, covered by colluvial deposits.**
- 22 Moderate yellowish brown (10 YR 5/4) silt, **9 feet 11 inches thick, tabular, moderately consolidated, massive, well sorted, angular quartz, biotite, calcite cement. Forms steep slopes covered by colluvial deposits.**
- 23 Dark yellowish brown (10YR 4/2) silty clay, **21 foot 2 inches thick, tabular, moderately consolidated, massive, calcite cement. Silt is well sorted, angular quartz. Covered by colluvial deposits.**
- 24 Pale yellowish brown (10YR 6/2) very fine sandstone, **2 feet 3 inches thick, tabular, slightly consolidated, massive, well sorted, subangular quartz, lithic particles, calcite cement, covered by colluvial deposits.**

- 25 Dark yellowish brown (10YR 4/2) clay, **2 feet 6 inches thick, tabular, moderately consolidated, massive, some black organic material, covered by colluvial deposits.**
- 26 Very pale orange (10YR 8/2) silt, **3 feet 3 inches thick, tabular, slightly consolidated, massive, well sorted, angular quartz, biotite, calcite cement, covered by colluvial deposits.**
- 27 Moderate yellowish brown (10YR 5/4) medium sandstone, **4 feet 11 inches thick, tabular, slightly consolidated, massive, moderately sorted, rounded quartz, black lithic particles, clay, calcite cement, covered by colluvial deposits.**
- 28 Pale brown (5YR 5/2) clay, **4 feet 4 inches thick, tabular, well consolidated, steep slopes, massive, covered by colluvial deposits.**
- 29 Pale yellowish brown (10YR 6/2) silt, **7 feet 4 inches thick, tabular, can trace through vegetation for 100 foot laterally, slightly consolidated, massive, well sorted, angular quartz, biotite, calcite cement.**
- 30 Moderate brown (5YR 4/4) medium sandstone, **12 feet 8 inches thick, channel deposit outlined by vegetation, 40 foot lateral exposure, lenticular, unconsolidated, water seepage, well sorted angular quartz, 1% black lithic particles, yellow coating on grains, calcite cement, fining upward to fine sandstone, covered by colluvial deposits.**
- 31 Pale yellowish brown (10YR 6/2) silt, **7 feet 5 inches thick, lenticular, 70 feet wide, well consolidated, forms 4 to 6 foot high cliffs, water seepage on bottom, massive, well sorted, angular, quartz, biotite, calcite cement.**
- 32 Dark yellowish brown (10YR 4/2) clay, **1 foot 6 inches thick, tabular, well consolidated, massive, black organic material, calcite present, covered by colluvial deposits.**
- 33 Dark yellowish brown (10YR 4/2) silt, **1 foot 6 inches thick, tabular, well consolidated, massive, well sorted, angular quartz, biotite, calcite cement, covered by colluvial deposits.**
- 34 Dark yellowish brown (10YR 4/2) very fine sandstone, **2 feet 6 inches thick, tabular, well consolidated, massive, calcite, reddish color in top 4 inches.**
- 35 Pale yellowish brown (10YR 6/2) very fine sandstone, **2 feet 6 inches thick, tabular, 100 foot lateral exposure, very well consolidated, massive, well sorted, subangular quartz, biotite, black lithic particles, yellow coating on grains, forms 2 foot high cliff to the east, covered by colluvial deposits to the west.**
- 36 Moderately yellowish brown (10YR 5/4) silty clay, **3 feet 0 inches thick, tabular, slightly consolidated, massive, mottled red and brown in top 8 inches, yellowish brown in lower part. Silt is well sorted, angular quartz, biotite. Calcite present. Covered by colluvial deposits.**
- 37 Pale yellowish brown (10YR 6/2) very fine sandstone, **7 feet 2 inches thick, tabular, unconsolidated, massive, well sorted, subangular quartz, biotite, volcanic glass, calcite cement, covered by colluvial deposits.**
- 38 Dark yellowish brown (10YR 4/2) clay, **2 feet 10 inches thick, tabular, moderately consolidated, massive, black organic material, calcite, covered by colluvial deposits.**

- 39 Pale yellowish brown (10YR 6/2) silt, **4 feet thick 2 inches thick, tabular, slightly consolidated, massive, well sorted, angular quartz, biotite, black lithic particles, calcite cement, covered by colluvial deposits.**
- 40 Dark yellowish brown (10YR 4/2) clay, **1 foot 8 inches thick, tabular, moderately consolidated, massive, black organic material, calcite, covered by colluvial deposits.**
- 41 Pale yellowish brown (10YR 6/2) fine sandstone, **11 inches thick, tabular, moderately consolidated, massive, moderately sorted, subrounded quartz, lithic particles, calcite cement, covered by colluvial deposits.**
- 42 Pale yellowish brown (10YR 6/2) fine sandstone, **4 feet 10 inches thick, lenticular channel deposit suggested by vegetation, unconsolidated, well sorted, subrounded quartz, biotite, black lithic particles, calcite cement, covered by colluvial deposits.**
- 43 Very pale orange (10YR 8/2) very fine sandstone, **2 feet 0 inches thick, tabular, curved, on bottom of a large channel deposit, 100 foot lateral exposure, forms a 2 foot high cliff, slightly consolidated, 2 1/2 inch laminations, well sorted, subrounded quartz, biotite, yellow coating on grains.**
- 44 Dark yellowish brown (10YR 4/2) silty clay, **2 feet 2 inches thick, tabular, moderately consolidated, massive, covered by colluvial deposits. Silt is well sorted, angular quartz.**
- 45 Pale yellowish brown (10YR 6/2) silt, **2 feet 0 inches thick, tabular, slightly consolidated, massive, well sorted, angular quartz, biotite, lithic particles, calcite cement, covered by colluvial deposits.**
- 46 Dark yellowish brown (10YR 4/2) clay, **9 feet 0 inches thick, tabular, massive, poorly consolidated, fissile, covered by colluvial deposits.**
- 47 Pale yellowish brown (10YR 6/2) silt, **3 feet 3 inches thick, tabular, slightly consolidated, massive, well sorted, angular quartz, biotite, calcite cement, covered by colluvial deposits.**
- 48 Dusky brown (5YR 2/2) clay, **1 foot 0 inches thick, tabular, massive, moderately consolidated, black organic material, covered by colluvial deposits.**
- 49 Pale yellowish brown (10YR 6/2) very fine sandstone, **1 foot 10 inches thick, tabular, slightly consolidated, massive, well sorted, subangular quartz, black lithic particles, biotite, calcite cement, covered by colluvial deposits.**
- 50 Dusky brown (5YR 2/2) clay, **2 feet 5 inches thick, tabular, massive, moderately consolidated, black organic material, covered by colluvial deposits.**
- 51 Pale yellowish brown (10YR 6/2) very fine sandstone, **3 feet 0 inches thick, lenticular, vegetation outlines channel, unconsolidated, well sorted, angular quartz, black lithic particles, biotite, covered by colluvial deposits.**
- 52 Pale yellowish brown (10YR 6/2) silt, **2 feet 4 inches thick, tabular, slightly consolidated, massive, massive, well sorted, angular, quartz, black lithic particles, biotite, calcite cement, covered by colluvial deposits.**
- 53 Dark yellowish brown (10YR 4/2) clay, **1 foot 0 inches thick, tabular, massive, moderately consolidated, fissile, calcite present, covered by colluvial deposits.**

- 53 Dark yellowish brown (10YR 4/2) clay, **1 foot 0 inches thick, tabular, massive, moderately consolidated, fissile, calcite present, covered by colluvial deposits.**
- 54 Pale yellowish brown (10YR 6/2) very fine sandstone, **2 feet 6 inches thick, tabular, unconsolidated, massive, well sorted, rounded, quartz, biotite, volcanic glass, yellow coating on grains, calcite cement, covered by colluvial deposits.**
- 55 Pale yellowish brown (10YR 6/2) very fine sandstone, **1 foot 3 inches thick, tabular, slightly consolidated, massive, well sorted, subangular quartz, feldspar, biotite, yellow coating on grains, calcite cement, covered by colluvial deposits.**
- 56 Pale yellowish brown (10YR 6/2) very fine sandstone, **3 feet 9 inches, channel deposit, lenticular, outlined by vegetation, 20 feet wide, unconsolidated, well sorted, angular quartz, volcanic glass, biotite, calcite cement, covered by colluvial deposits.**
- 57 Pale yellowish brown (10YR 6/2) fine sandstone, **4 feet 9 inches, tabular, unconsolidated, massive, well sorted, rounded quartz, volcanic glass, biotite, calcite cement, covered by colluvial deposits.**
- 58 Pale yellowish brown (10YR 6/2) fine sandstone, **2 feet 1 inch thick, tabular, slightly consolidated, massive, well sorted, subangular, quartz, volcanic glass, hematite, calcite nodules, calcite cement, covered by colluvial deposits.**
- 59 Dark yellowish brown (10YR 4/2) medium sandstone, **5 feet 2 inches thick, tabular, unconsolidated, moderately sorted, subrounded, quartz, clay particles, basaltic particles, calcite cement massive, covered by colluvial deposits.**
- 60 Pale yellowish brown (10YR 6/2) fine sandstone, **2 feet 9 inches thick, Tabular, poorly consolidated, massive, well sorted, subangular quartz, feldspars, biotite, black lithic particles, yellow coating on grains, covered by colluvial deposits.**
- 61 Dusky yellowish brown (10YR 2/2) clay, **9 inches thick, tabular, moderately consolidated, massive, covered by colluvial deposits.**
- 62 Pale yellowish brown (10YR 6/2) diatomaceous shale, **1 foot 6 inches thick, tabular, 400 foot lateral exposure to the west, covered by colluvial deposits to the east, laminated, gypsum crystals.**
- 63 Grayish brown (5YR 3/2) volcanic ash, **9 inches thick, tabular, well consolidated, basaltic, green olivine, calcite, covered by colluvial deposits.**
- 64 Dark yellowish brown (10YR 4/2) clay, **3 feet 6 inches thick, tabular, poorly consolidated, calcite, covered by colluvial deposits.**
- 65 Dark yellowish brown (10YR 4/2) fine sandstone, **2 feet 0 inches thick, tabular, slightly consolidated, massive, moderately sorted, subrounded quartz, volcanic glass, biotite, calcite cement, covered by colluvial deposits.**
- 66 Pale yellowish brown (10YR 6/2) very fine sandstone, **2 feet 7 inches thick, tabular, slightly consolidated, massive, well sorted, subrounded quartz, volcanic glass, biotite, hematite, calcite cement, covered by colluvial deposits.**
- 67 Dark yellowish brown (10YR 4/2) medium sandstone, **18 feet 9 inches thick, lenticular, poorly consolidated, lens outlined by vegetation, 90 feet wide, well sorted, rounded quartz, black volcanic glass, apatite, calcite nodules, calcite cement, covered by colluvial deposits.**

- 68 Pale yellowish brown (10YR 6/2) medium sandstone, **2 feet 5 inches thick, tabular, 10 foot lateral exposure, poorly consolidated, massive, moderately sorted, rounded quartz, volcanic glass, biotite, clay.**
- 69 Pale yellowish brown (10YR 6/2) medium sandstone, **4 feet thick, channel deposit, 5 foot later exposure, unconsolidated, well sorted, subangular quartz, feldspar, volcanic glass, calcite cement.**
- 70 pale yellowish brown (10YR 6/2) very fine sandstone, **1 foot 0 inches thick, tabular, 4 foot lateral exposure, slightly consolidated, well sorted, subangular, quartz, volcanic glass, biotite, calcite cement.**
- 71 Pale yellowish brown (10YR6/2) coarse sandstone, **6 feet 3 inches thick, channel deposit, lenticular, 40 feet wide, unconsolidated, moderately sorted, subrounded quartz, volcanic glass, feldspar calcite nodules, biotite, calcite crystals.**
- 72 Very pale orange (10YR 8/2) very fine sandstone, **9 inches thick, tabular, 8 foot lateral exposure, slightly consolidated, well sorted, angular quartz, volcanic glass, biotite, gypsum.**
- 73 Grayish brown (5YR 3/2) basaltic ash, **4 inches thick, tabular, unconsolidated, basaltic, 4 feet above bottom of channel (#81), fine grain, black volcanic glass, quartz, feldspar, gypsum**
- 74 Pale yellowish brown (10YR 6/2) medium sandstone, **10 feet 0 inches thick, channel deposit, lenticular, 70 foot wide, poorly consolidated, well sorted, rounded quartz, volcanic glass, gypsum.**
- 75 Pale yellowish brown (10YR 6/2) silt, **10 feet 0 inches thick, tabular, 100 foot lateral exposure, moderately consolidated, laminated, mottled red spots, well sorted, angular quartz, biotite, gypsum.**
- 76 Brownish black (5YR 3/1) basaltic ash, **5 inches thick, basaltic ash, volcanic glass, feldspars, gypsum, can be traced laterally to connect with unit #77.**
- 77 Light brownish gray (5YR 6/1) medium sandstone, **39 feet 5 inches thick, major river channel, 200 feet wide, lenticular, 3 foot sand waves exposed, red diatomaceous shale draped over sand waves, cross trough bedding, fossil beaver skull found at bottom of unit, rip up clasts of diatomaceous shale, and clay, sand is moderately sorted, subangular quartz, biotite, volcanic glass, yellow coating on grains.**
- 78 Grayish brown (5YR 3/2) basaltic ash, **5 inches thick, basaltic ash, tabular, 100 foot lateral exposure, well consolidated, massive, well sorted, angular quartz, black volcanic glass, feldspar, citrine, gypsum.**
- 79 Moderately yellowish brown (10YR 5/4) clay, **1 foot 0 inches thick, tabular, well consolidated, massive, poorly sorted, rounded quartz, black lithic particles, gypsum, biotite, covered by colluvial deposits.**
- 80 Pale yellowish brown (10YR 6/2) silt, **7 feet 0 inches thick, tabular, unconsolidated, massive, well sorted, subangular quartz, black lithic particles, biotite, gypsum, calcite cement, covered by colluvial deposits.**
- 81 Dark yellowish brown (10YR 4/2) silty clay, **4 feet 8 inches thick, tabular, unconsolidated, massive, 200 m laterally continuous exposure, fissile, gypsum, biotite,**

black lithic particles, silt is well sorted, angular, quartz, calcite cement, covered by colluvial deposits.

82 Pale yellowish brown (10YR 6/2) very fine sandstone, **5 feet 8 inches thick, tabular, slightly consolidated, massive, moderately sorted, angular quartz, black lithic particles, yellow coating on the grains, calcite cement, covered by colluvial deposits.**

83 Pale yellowish brown (10YR 6/2) fine sandstone, **6 feet 3 inches thick, tabular, unconsolidated, massive, moderately sorted, rounded quartz, black lithic particles, yellow coating on grains, calcite cement, covered by colluvial deposits.**

84 Pale yellowish brown (10YR 6/2) silt, **3 feet 0 inches thick, tabular, slightly consolidated, massive, well sorted, subrounded quartz, biotite, gypsum, calcite cement, covered by colluvial deposits.**

85 Dark yellowish brown (10YR 4/2) clay, **5 feet 6 inches thick, tabular, unconsolidated, massive, black lithic particles, calcite cement, covered by colluvial deposits.**

86 Pale yellowish brown (10YR 6/2) silt, **3 feet 0 inches thick, Tabular, slightly consolidated, massive, well sorted, rounded, quartz, biotite, covered by colluvial deposits.**

87 Dark yellowish brown (10YR 4/2) clay, **1 foot 0 inches thick, massive, moderately consolidated, lithic particles, biotite, calcite cement, covered by colluvial deposits.**

88 Pale yellowish brown (10YR 6/2) silt, **1 foot 6 inches thick, tabular, unconsolidated, massive, moderately sorted, subangular, quartz, black lithic particles, yellow coating on grains, calcite cement, covered by colluvial deposits.**

89 Pale yellowish brown (10YR 6/2) fine sandstone, **3 feet 0 inches thick, Channel deposits, lenticular, 12 feet wide, unconsolidated, outlined by vegetation, moderately sorted, subrounded quartz, biotite, muscovite, gypsum, calcite cement, covered by colluvial deposits.**

90 Dark yellowish brown (10Yr 4/2) medium sandstone, **2 feet 6 inches thick, tabular, unconsolidated, massive, moderately sorted, subrounded, quartz, black lithic particles, biotite, gypsum, calcite cement, covered by colluvial deposits.**

91 Pale yellowish brown (10YR 6/2) fine sandstone, **6 feet 0 inches thick, tabular, unconsolidated, massive, well sorted, subrounded quartz, feldspar, volcanic glass, biotite, yellow stain on particles, calcite cement, covered by colluvial deposits.**

92 Pale yellowish brown (10YR 6/2) fine sandstone, **1 foot 10 inches thick, channel deposits, lenticular, 30 feet wide, unconsolidated, moderately sorted, subangular, quartz, volcanic glass, biotite, yellow coating on grains, calcite cement.**

93 Dark yellowish brown (10YR 4/2) clay, **1 foot 0 inches thick, tabular, moderately consolidated, massive, covered by colluvial deposits, gypsum crystals, calcite cement.**

94 Pale yellowish brown (10YR 6/2) very fine sandstone, **9 feet 2 inches thick, tabular, unconsolidated, massive, well sorted, subangular quartz, biotite, black lithic particles, calcite cement, covered by colluvial deposits.**

95 Dark yellowish brown (10YR 4/2) medium sandstone, **4 feet 0 inches thick, tabular, unconsolidated, massive, poorly sorted. subrounded quartz, lithic particles, biotite, gypsum crystals, calcite cement, covered by colluvial deposits.**

- 96 Pale yellowish brown (10YR 6/2) very fine sandstone, **3 feet 6 inches thick, Tabular, moderately consolidated, massive, moderately sorted, subrounded quartz, black lithic particles, hematite, biotite, gypsum crystals, calcite cement, covered by colluvial deposits.**
- 97 Dark yellowish brown (10YR 4/2) sandy clay, **1 foot 0 inches thick, tabular, poorly consolidated, 100 m laterally continuous exposure, sand is poorly sorted, subrounded, quartz, biotite, black volcanic glass.**
- 98 Pale yellowish brown (10YR 6/2) silt, **1 foot 8 inches thick, Tabular, moderately consolidated, massive, well sorted, angular quartz, biotite, black lithic particles, calcite cement, covered by colluvial deposits.**
- 99 Dark yellowish brown (10YR 4/2) clay, **1 foot 7 inches thick, tabular, moderately consolidated, covered by colluvial deposits.**
- 100 Dusky yellowish brown (10YR 2/2) sandy clay, **2 feet 0 inches thick, tabular, poorly consolidated, popcorn texture on the surface, sand is fine grained and contains black lithic particles and gypsum crystals, covered by colluvial deposits.**
- 101 Dark yellowish brown (10YR 4/2) clay, **1 foot 11 inches thick, tabular, moderately consolidated, massive, poorly sorted, rounded quartz, black lithic particles, biotite, gypsum, feldspars, calcite cement, covered by colluvial deposits.**
- 102 Pale yellowish brown (10Yr 6/2) silt, **2 feet 4 inches thick, Tabular, unconsolidated, massive, well sorted, subrounded quartz, biotite, muscovite, black volcanic glass, calcite cement, covered by colluvial deposits.**
- 103 Dusky yellowish brown (10Yr 2/2) clay, **2 feet 4 inches thick, Tabular, moderately consolidated, massive, gypsum crystals, calcite cement, covered by colluvial deposits.**
- 104 Pale yellowish brown (10YR 6/2) silt, **2 feet 6 inches thick, tabular, unconsolidated, massive, well sorted subangular quartz, black lithic particles, biotite, covered by colluvial deposits.**
- 105 Dark yellowish brown (10YR 4/2) very fine sandstone, **3 inches thick, tabular, moderately consolidated, tabular, moderately sorted, subangular, quartz, feldspar, black lithic particles, volcanic glass, muscovite, calcite cement, covered by colluvial deposits.**
- 106 Pale yellowish brown (10YR 6/2) fine sandstone, **4 feet 6 inches thick, Tabular, unconsolidated, massive, moderately sorted, subrounded quartz, hornblende, biotite, volcanic glass, gypsum, calcite cement, covered by colluvial deposits.**
- 107 Pale yellowish brown (10YR 6/2) fine sandstone, **6 feet 6 inches thick, epsilon cross bedding, moderately sorted, subrounded quartz, feldspar, biotite, lithic particles, hornblende, apatite, calcite cement.**
- 108 Dark yellowish brown (10YR 4/2) medium sandstone, **14 feet 9 inches thick, channel deposits 325 feet wide, bounded by silt, well sorted, subrounded, quartz, feldspar, biotite, lithic particles, hornblende, apatite, calcite cement.**
- 109 Pale yellowish brown (10YR 6/2) silt, **11 feet thick, tabular, slightly consolidated, massive, well sorted, angular quartz, hematite, biotite, calcite cement, covered by colluvial deposits.**

- 110 Dusky yellowish brown (10YR 2/2) silt, **1 foot 6 inches thick, tabular, well consolidated, massive, 45° slope, well sorted, angular quartz, biotite, gypsum crystals, calcite cement, covered by colluvial deposits.**
- 111 Pale yellowish brown (10YR 6/2) silt, **7 feet thick, layered, tabular, unconformable contact with channel deposits and silts to the left side, well sorted, subrounded, quartz, biotite, gypsum, calcite cement.**
- 112 Light gray ash, **4 inches thick, rhyolitic, extremely well consolidated, poorly sorted, clast supported, subangular quartz, feldspars, black lithic particles, 100 meters exposed, drapes down into the channel formed by unit #24, located 6 feet from the bottom of the channel.**
- 113 Light brownish gray (5YR 6/1) medium sandstone, **14 feet thick, Channel fill, ripple marks in top 2 feet, flow direction approximately N50°E, moderately sorted, subrounded, quartz, biotite, black lithic particles, apatite, gypsum, calcite cement, contains unit #25.**
- 114 Pale yellowish brown (10YR 6/2) silt, **9 inches thick, channel, very well consolidated, moderately sorted, subangular, quartz, gypsum, hematite, biotite, calcite cement.**
- 115 Pale yellowish brown (10YR 6/2) fine sandstone, **5 inches thick, tabular, moderately consolidated, massive, well sorted, rounded quartz, black lithic particles, calcite cement, fining upward.**
- 116 Pale yellowish brown (10 YR 6/2) very fine sandstone, **3 feet 3 inches thick, tabular, moderately consolidated, massive, moderately sorted, rounded, quartz, biotite, hematite, gypsum, calcite cement.**
- 117 Light olive gray (5Y 3/2) clay, **1 foot 8 inches thick, tabular, well consolidated, massive, covered by colluvial deposits.**
- 118 Moderately yellowish brown (10YR 5/4) silt, **3 feet 3 inches thick, tabular, well consolidated, massive, well sorted, rounded, quartz, biotite, gypsum crystals, calcite cement, covered by colluvial deposits.**
- 119 Olive gray (5Y 3/2) clay, **10 inches thick, tabular, well consolidated, contains gypsum crystals.**
- 120 Very pale orange (10YR 8/2) fine silt, **5 feet 6 inches thick, tabular, well consolidated, laminated, well sorted, angular quartz, biotite, calcite cement, approximately 400 meters exposure, pop corn texture on surface.**
- 121 Olive green gray (5Y 5/2) very fine sandstone, **10 feet 6 inches thick, lenticular, unconsolidated, massive, moderately sorted, rounded, quartz, biotite, hornblende, gypsum crystals, calcite cement, 60 feet wide, surrounded by light brown silt.**
- 122 Dark yellowish brown (10YR 4/2) clay, **2 feet 0 inches thick, tabular, well consolidated, massive, contains gypsum crystals, calcite present, covered by colluvial deposits.**
- 123 Dark yellowish brown (10 YR 4/2) clay, **4 feet 0 inches thick, tabular, well consolidated, massive, contains gypsum crystals.**
- 124 Pale yellowish brown (10YR 6/2) fine sandstone, **4 feet 4 inches thick, tabular, slightly consolidated, massive, well sorted, well rounded, quartz, biotite, hornblende, garnet, gypsum. Forms 45° slopes.**

- 125 Grayish brown (5YR 2/2) clay, **2 feet 0 inches thick, tabular, well consolidated, massive, gypsum crystals. Used as a marker bed to move the stratigraphic section.**
- 126 Dark yellowish brown (10YR 4/2) fine sandstone, **2 feet 10 inches thick, tabular, unconsolidated, massive, well sorted, subangular, quartz, biotite, gypsum, coarsens upward, darkens upward.**
- 127 Pale brown 5YR 5/2 fine silt, **1 foot 1 inches thick, tabular, well consolidated, massive, well sorted, rounded, quartz, biotite, garnet, calcite cement.**
- 128 Grayish brown (5YR 3/2) clay, **7 feet 9 inches thick, tabular, slightly consolidated, massive, gypsum crystals, covered by colluvial deposits.**
- 129 Pale yellowish brown (10YR 6/2) fine sandstone, **1 foot 2 inches thick, tabular, moderately consolidated, well sorted, subrounded, quartz, biotite, black lithic particles, hematite, calcite cement.**
- 130 Pale brown (5YR 5/2) silty clay, **2 feet 11 inches thick, Tabular, moderately consolidated, massive, well sorted, angular, quartz, black lithic particles, and clay platelets.**
- 131 Pale yellowish brown (10YR 6/2) silt, **4 feet 10 inches thick, tabular, unconsolidated, massive, covered by colluvial deposits, powdery, well sorted, subangular, quartz, black lithic particles, hematite, calcite cement.**
- 132 Olive Gray (5Y 4/1) clay, **1 foot 7 inches thick, tabular, well consolidated, massive, gypsum crystals, black lithic particles.**
- 133 Dark yellowish brown clay, **3 feet 3 inches thick, tabular, well consolidated, massive, contains gypsum crystals and calcite.**
- 134 Pale yellow brown (10YR 6/2) fine sandstone, **2 feet 0 inches thick, tabular, unconsolidated, massive, covered by colluvial deposits, moderately sorted, moderately rounded, quartz, pyrite, hematite, black lithic particles, calcite cement.**
- 135 Pale brown (5YR 5/2) silty clay, **7 feet 7 inches thick, tabular, well consolidated, massive, forms cliffs, pop corn texture on the surface, grayish green color below weathering surface, silt is very fine containing quartz and black lithic particles. Calcite exists in this unit.**
- 136 Pale yellowish Brown (10YR 6/2) silt, **8 feet 9 inches thick, tabular, well consolidated, massive, forms cliffs, .25 mile exposure, some clay content, well sorted, subrounded, quartz, 1% black lithic particles, gypsum crystals.**

APPENDIX B

PETROGRAPHIC DESCRIPTIONS

Section 21 Column

Top of Column

1. **Pale yellowish brown (10YR 6/2) cobble conglomerate**, poorly sorted, rounded quartz, lithic particles, biotite, feldspar, calcite cement, moderately consolidated, tabular, 9 feet 11 inches thick, matrix supported.
2. **Pale yellowish brown (10YR 6/2) pebble conglomerate**, moderately sorted, subrounded quartz, lithic particles, dacite and quartzite pebbles, moderately consolidated, channel, 12 feet 11 inches thick, Tuanna Gravel.
3. **Pale yellowish brown (10YR 6/2) fine sandstone**, poorly sorted, subrounded quartz, volcanic glass, biotite, calcite cement, poorly consolidated, 5 feet thick, tabular.
4. **Pale yellowish brown (10YR 6/2) fine sandstone**, moderately sorted, subrounded quartz, volcanic glass, calcite cement, very poorly consolidated, 8 feet 10 inches thick, channel, blow out area.
5. **Pale yellowish brown (10YR 6/2) fine sandstone**, moderately sorted, angular quartz, volcanic glass, calcite nodules, calcite cement, moderately consolidated, 8 feet 11 inches thick, tabular.
6. **Dark yellowish brown (10YR 5/4) clay**, massive, calcite, 5 feet 10 inches thick, tabular.
7. **Very pale orange (10YR 8/2) medium sandstone**, poorly sorted, rounded quartz and volcanic glass, calcite cement, well consolidated, 1 foot 10 inches thick, massive, tabular.
8. **Dark yellowish brown (10YR 4/2) clay**, massive, friable, calcite nodules on the bottom, 6 inches thick.
9. **Pale yellowish brown (10YR 6/2) very fine sandstone**, moderately sorted, subangular quartz and volcanic glass, calcite cement, moderately consolidated, 3 feet 7 inches thick, massive, tabular, calcite nodules in the top 3 inches.
10. **Moderate yellowish brown (10YR 5/4) fine sandstone**, moderately sorted, subangular quartz, volcanic glass, clay fragments (50%), carnotite, calcite cement, moderately consolidated, 3 feet thick, massive, tabular, clay is possible rip up clasts.
11. **Very pale orange (10YR 8/2) silt**, well sorted, angular quartz, volcanic glass, calcite cement, well consolidated, 1 foot thick, massive, tabular, 1 inch of bentonite clay on top.
12. **Very pale orange (10YR 8/2) clay**, massive tabular, moderately consolidated, 8 inches thick, carbon in the bottom.
13. **Pale yellowish brown (10YR 6/2) silt**, well sorted, angular quartz, carbon, calcite cement, moderately consolidated, 10 inches thick, massive tabular, 1 inch thick ash on top.
14. **Moderate yellowish brown (10YR 5/4) clay**, friable, massive, tabular, sandy (medium sand, quartz and volcanic glass) moderately consolidated, 1 foot 2 inches thick.

15. **Very pale orange (10YR 8/2) clay**, contains calcite, moderately consolidated, 1 foot 9 inches thick.
16. **Dark yellowish brown (10YR 4/2) clay**, silty (silt is well sorted, angular quartz), carbon, calcite.
17. **Pale yellowish brown (10YR 6/2) silt**, no sample for this unit, unit is moderately consolidated, 3 feet 4 inches thick, massive, tabular,.
18. **Pale yellowish brown (10YR 6/2) clay**, biotite, carbon, moderately consolidated, 1 foot 7 inches thick, massive, tabular.
19. **Very pale orange (10YR 8/2) silt**, well sorted angular quartz, volcanic glass, well consolidated, 4 feet 4 inches thick, massive, tabular
20. **Pale yellowish brown (10YR 6/2) clay**, carbon, calcite, moderately consolidated, 2 feet 7 inches thick, massive, tabular.
21. **Pale yellowish brown silt (10YR 6/2) silt and medium sand**, bimodal, subangular quartz, volcanic glass, carbon, calcite cement, moderately consolidated, 1 foot thick, massive, tabular.
22. **Pale yellowish brown (10YR 6/2) silt**, well sorted, angular quartz, volcanic glass, clay nodules, moderately consolidated, 1 foot 6 inches thick, massive, tabular.
23. **Grayish orange (10YR 7/4) very fine sandstone**, well sorted, angular quartz, volcanic glass, muscovite, calcite cement, moderately consolidated, 2 feet 6 inches thick, massive, channel.
24. **Dark yellowish gray (10YR 4/2) fine sandstone**, moderately sorted, subangular quartz, volcanic glass, feldspar, 1-2 mm clay nodules, calcite cement, well consolidated, 17 feet 4 inches thick, stream channel 150 feet wide.
25. **Dark yellowish brown (10YR 4/2) clay**, massive, tabular, moderately consolidated, bottom of channel, carbon in the top 2 inches, 1-2 mm clay nodules, calcite nodules, white in top 2 inches, 1 foot thick.
26. **Very pale orange (10YR 7/2) silt**, well sorted, angular quartz, carbon, volcanic glass, calcite cement, well consolidated, 2 feet 10 inches thick, massive, tabular.
27. **Pale yellowish brown (10YR 6/2) clay**, moderately consolidated, 10 inches thick, massive, tabular, mottled, carbon.
28. **Very pale orange (10YR 7/2) clay**, moderately consolidated, 8 inches thick, carbon, massive, tabular.
29. **Dark yellowish brown (10YR 4/2) clay**, carbon, calcite nodules, moderately consolidated, 1 foot 8 inches thick, massive, tabular.
30. **Pale yellowish brown (10YR 6/2) fine sandstone**, well sorted, subangular quartz, volcanic glass, biotite, clay nodules, poorly consolidated, 1 foot 9 inches thick, massive, tabular.
31. **Pale yellowish brown (10YR 6/2) clay**, friable, moderately consolidated, 1 foot 1 inch thick, massive, tabular.

32. **Pale yellowish brown (10YR 6/2) silt**, well sorted, angular quartz, volcanic glass, biotite, calcite cement, moderately consolidated, 1 foot 4 inches thick, massive, tabular.
33. **Pale yellowish brown (10YR 6/2) clay**, friable, moderately consolidated, 1 foot 1 inch thick, massive, tabular.
34. **Very pale orange (10YR 8/2) very fine sandstone**, subangular quartz, biotite, volcanic glass, calcite cement, moderately consolidated, 1 foot 7 inches thick, massive, tabular.
35. **Pale yellowish brown (10YR 6/2) clay**, friable, carbon, moderately consolidated, 2 feet 4 inches thick, massive, tabular.
36. **Very pale orange (10YR 8/2) silt**, well sorted, angular quartz, biotite, calcite cement, well consolidated, 1 foot 3 inches thick, massive, tabular.
37. **Pale yellowish brown (10YR 6/2) fine sandstone**, poorly sorted, subrounded quartz, volcanic glass, 40% clay particle, calcite nodules, calcite cement, poorly consolidated, 1 foot 4 inches thick, massive, tabular. Bottom of 60-foot wide channel.
38. **Pale yellowish brown (10YR 6/2) clay**, carbon, calcite nodules, moderately consolidated, 1 foot 9 inches thick, massive, tabular.
39. **Pale yellowish brown (10YR 6/2) clay**, carbon, well consolidated, 10 inches thick, massive, tabular.
40. **Pale yellowish brown (10YR 6/2) fine sandstone**, no sample, 35-foot wide channel, 2 feet thick.
41. **Very pale orange (10YR 8/2) fine sandstone**, well sorted, subangular, quartz, granite rock fragments, clay nodules, volcanic glass, biotite, calcite cement, poorly consolidated, 3 feet 6 inches thick, top of channel, fines upward.
42. **Pale yellowish brown (10YR 6/2) fine sandstone**, moderately sorted, subrounded quartz, volcanic glass, biotite, granite rock fragments, clay nodules, calcite cemented, poorly consolidated, 1 foot 7 inches thick, 10 foot wide channel.
43. **Pale yellowish brown (10YR 6/2) clay**, carbon, moderately consolidated, 1 foot 4 inches thick, massive, tabular.
44. **Dark yellowish brown (10YR 4/2) very fine silt**, well sorted, angular quartz, volcanic glass, calcite cement, well consolidated, 1 foot 5 inches thick, massive, tabular.
45. **Pale yellowish brown (10YR 6/2) clay**, carbon, calcite, well consolidated, 1 foot 4 inches thick, massive, tabular.
46. **Pale yellowish brown (10YR 6/2) clay**, calcite nodules, moderately consolidated, 3 feet thick, massive, tabular
47. **Dark yellowish brown (10YR 4/2) clay**, carbon, moderately consolidated, 1 foot 3 inches thick, massive, tabular.
48. **Pale yellowish brown (10YR 7/2) silt**, well sorted, angular quartz, volcanic glass, calcite cement, moderately consolidated, 9 inches thick, massive, tabular.
49. **Pale yellowish brown (10YR 6/2) clay**, friable, carbon, moderately consolidated, 10 inches thick, massive, tabular.

50. **Pale yellowish brown (10YR 6/2) silt**, well sorted, angular quartz, volcanic glass, calcite cement, moderately consolidated, 2 feet 6 inches thick, massive, tabular.
51. **Dark yellowish brown (10YR 4/2) clay**, carbon, moderately consolidated, 9 inches thick, massive, tabular.
52. **Pale yellowish brown (10YR 6/2) fine sandstone**, moderately sorted, subrounded quartz, volcanic glass, biotite, basalt, calcite cement, well consolidated, 1 foot thick, massive, tabular.
53. **Pale yellowish brown (10YR 6/2) very fine sandstone**, well sorted, subangular quartz, volcanic glass, biotite, sandstone nodules, calcite nodules, calcite cement, poorly consolidated, 1 foot 6 inches thick, channel, cross bedding.
54. **Pale yellowish brown (10YR 7/2) very fine sandstone**, moderately sorted, subangular quartz, volcanic glass, basalt, biotite, calcite cement, moderately consolidated, 1 foot 6 inches thick, massive, tabular.
55. **Dark yellowish brown (10YR 4/2) medium sandstone**, well sorted, subangular quartz, volcanic glass, basalt, clay nodules, calcite cement, unconsolidated, 11 feet 4 inches thick, fines upward to very fine sandstone, well consolidated sandstone nodules in the top 10 feet.
56. **Pale yellowish brown (10YR 6/2) medium sandstone**, moderately sorted, sub rounded quartz, volcanic glass, clay nodules, calcite cement, well consolidated, 1 foot 9 inches thick, clay nodules are same shape and size as sand grains, massive, tabular.
57. **Pale yellowish brown (10YR 7/2) silt**, well sorted, angular quartz, volcanic glass, biotite, calcite cement, poorly consolidated, 4 feet 5 inches thick, massive, tabular.
58. **Dark yellowish brown (10YR 5/2) clay**, friable, carbon, massive, tabular, calcite, moderately consolidated, 10 inches thick.
59. **Very pale orange (10YR 8/2) clay**, massive, tabular, well-consolidated, 10 inches thick.
60. **Dark yellowish brown (10YR 4/2) clay**, carbon, bone fragments, calcite, massive, tabular, well consolidated, 8 inches thick.
61. **Pale yellowish brown (10YR 6/2) very fine sandstone**, well sorted, subangular quartz, volcanic glass, biotite, calcite cement, well consolidated, 1 foot 1 inches thick, 15 foot wide channel, massive.
62. **Pale yellowish brown (10YR 6/2) clay**, carbon, calcite nodules, well consolidated, 6 inches thick.
63. **Pale yellowish brown (10YR 7/2) silt**, well sorted, angular quartz, volcanic glass, biotite, calcite cement, well consolidated, 5 feet 2 inches thick, massive, tabular.
64. **Moderate yellowish brown (10YR 5/4) clay**, carbon, calcite nodules, very well consolidated, 6 inches thick, massive, tabular.
65. **Pale yellowish brown (10YR 7/2) clay**, carbon, well consolidated, 8 inches thick, massive, tabular.
66. **Grayish brown 5YR 3/2) clay**, laminar, very well consolidated, 11 inches thick, organic carbon, leaf imprints, gypsum, fossil roots.

67. **Pale yellowish brown (10YR 7/2) clay**, friable, silty (well sorted angular quartz, volcanic glass, biotite), well consolidated, 1 foot 10 inches thick, massive, tabular.
68. **Pale brown (5YR 5/2) medium sandstone**, moderately sorted, subangular quartz, volcanic glass, calcite cement, unconsolidated, 7 feet 1 inch thick, 70 foot wide channel.
69. **Pale yellowish brown (10YR 6/2) fine sandstone**, moderately sorted, subrounded quartz, volcanic glass, biotite, moderately consolidated, 4 feet thick, bottom of 70 foot wide channel.
70. **Moderate brown (5YR 4/4) shale**, diatomaceous, laminar, carbonaceous, 1 foot 8 inches thick.
71. **Dark yellowish brown (10YR 4/2) fine sandstone**, well sorted, subangular quartz, volcanic glass, biotite, unconsolidated, 3 feet 2 inches thick, lenticular, massive.
72. **Pale yellowish brown (10YR 6/2) silt**, well sorted, angular quartz, volcanic glass, biotite, moderately consolidated, 1 foot 10 inches thick, massive, tabular.
73. **Dark yellowish brown (10YR 4/2) clay**, well consolidated, 1 foot 2 inches thick, massive, tabular, 0.5 inch thick rhyolitic ash in the middle of this unit.
74. **Very pale orange (10YR 8/2) volcanic ash**, rhyolitic, glass, sanadine, carnotite unconsolidated, 7 inches thick, laminar.
75. **Grayish orange pink (5YR 7/2) fine sandstone**, moderately sorted, subrounded quartz, volcanic glass, poorly consolidated, 11 inches thick, massive, tabular.
76. **Dusky yellowish brown (10YR 2/2) volcanic ash**, basaltic, medium grain, poorly consolidated, 10 inches thick, massive, tabular.
77. **Pale yellowish brown (10YR 6/2) medium sandstone**, moderately sorted, subrounded quartz, volcanic glass, 1-2 mm clay balls, unconsolidated, 10 inches thick, massive, tabular.
78. **Dark yellowish brown (10YR 4/2) clay**, carbon, moderately consolidated, 10 inches thick, massive, tabular.
79. **Very pale orange (10YR 8/2) volcanic ash**, rhyolitic, welded tuff, lithic fragments, clearly visible along both sides of the canyon.
80. **Pale yellowish brown (10YR 6/2) silt**, well sorted, angular quartz, volcanic glass, poorly consolidated, 3 feet 8 inches thick, massive, tabular.
81. **Pale brown (5YR 5/2) clay**, fissile, moderately consolidated, 1 foot thick, massive, tabular.
82. **Pale yellowish brown (10YR 6/2) silt**, well sorted, subangular quartz, volcanic glass, poorly consolidated, 4 feet 7 inches thick, massive, tabular.
83. **Pale yellowish brown (10YR 6/2) clay**, moderately consolidated, 2 feet 2 inches thick, massive, tabular.
84. **Pale yellowish brown (10YR 6/2) silt**, well sorted, angular quartz, volcanic glass, poorly consolidated, 4 feet 7 inches thick, massive, tabular.

85. **Light olive gray (5Y 5/2) fine silt**, well sorted, angular quartz, volcanic glass, red nodules, moderately consolidated, 2 feet 6 inches thick, massive, tabular.
86. **Pale yellowish brown (10YR 6/2) silt**, well sorted, very angular quartz, biotite, moderately consolidated, 1 foot thick, massive, tabular, fissile.
87. **Pale yellowish brown (10YR 6/2) fine sandstone**, well sorted, subrounded quartz, volcanic glass, biotite, unconsolidated, 1 foot 7 inches thick, 8 foot wide channel.
88. **Pale yellowish brown (10YR 6/2) silt**, well sorted, angular quartz, volcanic glass, gypsum, red nodules, poorly consolidated, 2 feet 1 inch thick, massive, tabular.
89. **Pale yellowish brown (10YR 6/2) fine sandstone**, moderately sorted, angular quartz, volcanic glass, sanadine, poorly consolidated, 4 feet 2 inches thick, massive tabular.
90. **Pale yellowish brown (10YR 6/2) silt**, very well sorted, angular quartz, biotite, red nodules, moderately consolidated, 1 foot 9 inches thick, massive, tabular, solid red in top 4 inches.
91. **Pale yellowish brown (10YR 6/2) silt**, well sorted, angular quartz, biotite, moderately consolidated, 1 foot 9 inches thick, massive, tabular.
92. **Pale yellowish brown (10 YR 7/2) clay**, well consolidated, 9 inches thick, massive, tabular.
93. **Grayish brown (5YR 3/2) fine silt**, well sorted, angular quartz, volcanic glass, biotite, moderately consolidated, 2 feet 9 inches thick, massive, tabular.
94. **Dark yellowish brown (10YR 4/2) clay**, red nodules, poorly consolidated, 2 feet thick, massive, tabular.
95. **Pale yellowish brown (10YR 6/2) clay**, moderately consolidated, 2 feet thick, massive, lenticular.
96. **Pale brown (5YR 5/2) very fine sandstone**, poorly sorted, subrounded quartz, volcanic glass, calcite nodules, moderately consolidated, 1 foot 6 inches thick, laminated.
97. **Dark yellowish brown (10YR 4/2) fine sandstone**, moderately sorted, subrounded quartz, volcanic glass, gypsum crystals, poorly consolidated, 1 foot thick. Massive, tabular.
98. **Pale yellowish brown (10YR 6/2) silt**, well sorted, angular quartz, volcanic glass, poorly consolidated, 2 feet 7 inches thick, massive, tabular.
99. **Dark yellowish brown (10YR 4/2) clay**, silty, poorly consolidated, 1 foot 10 inches, massive, tabular.
100. **Pale yellowish brown (10YR 6/2) silt**, well sorted, angular quartz, volcanic glass, biotite, moderately sorted, 2 feet 7 inches thick, massive, tabular.
101. **Dark yellowish brown (10YR 4/2) fine sandstone**, poorly sorted, subangular quartz, volcanic glass, biotite, 2 mm clay balls, poorly consolidated, 6 inches thick, massive, tabular.
102. **Pale yellowish brown (10YR 6/2) fine sandstone**, moderately sorted, subrounded quartz, volcanic glass, biotite, unconsolidated, 2 feet thick, massive, lenticular.

- 103. Pale yellowish brown (10YR 6/2) very fine sandstone**, well sorted, angular quartz, volcanic glass, unconsolidated, 2 feet 1 inch thick, massive, tabular.
- 104. Dusky yellowish brown (10YR 2/2) clay**, carbon, silty, moderately consolidated, 1 foot 6 inch, massive, tabular.
- 105. Yellowish gray (5Y 8/1) shale**, diatomaceous, carbonaceous, leaf imprints, silty, 5 inches thick.
- 106. Pale brown (5YR 5/2) silt**, well sorted, angular quartz, volcanic glass, poorly consolidated, 4 feet 1 inch thick, massive, tabular, covered with unidentified black material.
- 107. Pale brown (5YR 5/2) very fine sandstone**, moderately sorted, subrounded quartz, volcanic glass, poorly consolidated, 1 foot thick, massive, tabular, white on top.
- 108. Dark yellowish brown (10YR 4/2) clay**, carbon, well consolidated, 6 inches thick, massive, tabular.
- 109. Pale yellowish orange (10YR 8/2) very fine sandstone**, moderately sorted, subangular quartz, volcanic glass, well consolidated, 7 inches thick, massive, tabular.
- 110. Pale yellowish orange (10YR 8/2) silt**, well sorted, angular quartz, volcanic glass, poorly consolidated, 1 foot thick, massive, tabular.
- 111. Grayish orange pink (5YR 7/2) shale**, diatomaceous, laminar, 3 inches thick.
- 112. Dark yellowish brown (10YR 4/2) silt**, well sorted, angular quartz, gypsum, 1 foot thick, red coating.
- 113. Dark yellowish brown (10YR 4/2) clay**, carbon, gypsum, 11 inches thick, massive, tabular.
- 114. Pale yellowish brown (10YR 6/2) very fine sandstone**, well, sorted, angular quartz, volcanic glass, biotite, 0.125 mm bivalve shell, red nodules, moderately consolidated, 1 foot 10 inches thick.
- 115. Dark reddish brown (10YR 3 /4) volcanic ash**, basaltic, coarse grain, subangular, 2 inches thick.
- 116. Pale yellowish brown (10YR 6/2) fine sandstone**, moderately sorted, subrounded quartz, volcanic glass, biotite, plagioclase, calcite nodules, moderately consolidated, 9 inches thick, massive, tabular.
- 117. Pale yellowish brown (10YR 6/2) fine sandstone**, poorly sorted, subangular quartz, volcanic glass, plagioclase, poorly consolidated, 2 feet 6 inches thick, channel.
- 118. Dark yellowish brown (10 YR 4/2) medium sandstone**, well sorted, subrounded quartz, volcanic glass, plagioclase, biotite, unconsolidated, 31 feet 8 inches thick, 240 foot wide channel, fines upward.
- 119. Pale yellowish brown (10YR 6/2) clay**, Carbon, fissile, massive, tabular.
- 120. Pale yellowish brown (10YR 6/2) silt**, well sorted, angular quartz, volcanic glass, biotite, moderately consolidated, 6 feet 5 inches thick, massive, tabular.

- 121. Pale brown (5YR 5/2) clay**, carbon, poorly consolidated, 2 feet 3 inches thick, massive, tabular.
- 122. Pale yellowish brown (10YR 7/2) very fine sandstone**, moderately sorted, subangular quartz, volcanic glass, muscovite, poorly consolidated, 2 feet 3 inches thick,, massive, tabular.
- 123. Pale yellowish brown (10YR 7/2) fine sandstone**, well sorted, subangular quartz, volcanic glass, biotite, unconsolidated, 2 feet 7 inches thick, massive, tabular.
- 124. Very pale orange (10YR 8/2) silt**, well sorted, angular quartz, biotite, volcanic glass, moderately consolidated, massive, tabular.
- 125. Light olive gray (5Y 5/2) clay**, carbon, grass leaf imprint, moderately consolidated, 7 inches thick, massive, tabular.
- 126. Pale yellowish brown (10YR 6/2) clay**, silty (well sorted, angular quartz), moderately consolidated, 9 inches thick, massive, tabular, shell hash, bivalve shells.
- 127. Grayish brown (5YR 3/2) clay**, silty, moderately consolidated, 11 inches thick, massive, tabular.
- 128. Pale yellowish brown (10YR 6/2) fine silt**, well sorted, angular quartz, biotite, carbon, poorly consolidated, 2 feet thick, massive, tabular.
- 129. Pale brown (5YR 5/2) silt**, well sorted, angular quartz, volcanic glass, biotite. moderately consolidated, 5 feet 6 inches thick, tabular massive, gradational contact with unit 128, alternating light brown and darker brown layers.
- 130. Pale yellowish brown (10YR 6/2) very fine sandstone**, well sorted, subangular quartz, volcanic glass, muscovite, poorly consolidated, 4 feet thick, massive, tabular.
- 131. Pale yellowish brown (10YR 6/2) silt**, well sorted, angular quartz, biotite, carbon, gypsum, moderately consolidated, 2 feet 1 " thick, massive, tabular, dark brown in top 3 inches of the unit.
- 132. Grayish brown (5YR 3/2) clay**, carbon, moderately consolidated, 8 inches thick, massive, tabular.
- 133. Very pale orange (10YR 8/2) silt**, well sorted, angular quartz, volcanic glass, biotite, well consolidated, 2 feet 7 inches thick, massive, tabular.
- 134. Dark yellowish brown (10YR 4/2) clay**, carbon, moderately consolidated, 1 foot 2 inches thick, massive, tabular.
- 135. Pale yellowish brown (10YR) very fine sandstone**, moderately sorted, angular quartz, volcanic glass, gypsum, biotite, poorly consolidated, 3 feet 9 inches thick, massive, tabular.
- 136. Grayish orange pink (5YR 7/2) clay**, moderately consolidated, 1 foot 6 inches thick, massive, tabular.
- 137. Grayish orange pink (5YR 7/2) very fine sandstone**, well sorted, angular quartz, biotite, volcanic glass, moderately consolidated, 3 feet 6 inches thick, massive, tabular.
- 138. Very pale orange (10YR 8/2) silt**, well sorted, angular quartz, biotite, volcanic glass, muscovite, moderately consolidated, 4 feet 8 inches thick, massive, tabular.

- 139. Pale brown (5YR 5/2) clay**, carbon, gypsum, ochre, moderately consolidated, 1 foot thick, massive, tabular, possible fossilized vegetation.
- 140. Pale yellowish brown (10YR 6/2) very fine sandstone**, moderately sorted, angular quartz, volcanic glass, massive, tabular.
- 141. Pale yellowish brown (10YR 6/2) silt**, well sorted, angular quartz, volcanic glass, biotite, gypsum, moderately consolidated, 11 inches thick, massive, tabular.
- 142. Pale yellowish brown (10YR 7/2) silt**, well sorted, angular quartz, volcanic glass, gypsum, poorly consolidated, 5 feet 8 inches thick, massive, tabular.
- 143. Pale brown (5YR 5/2) clay**, carbon, fissile, sandy (subangular quartz and volcanic glass), gypsum, well consolidated, 2 feet thick, massive, tabular.
- 144. Pale yellowish brown (10YR 6/2) very fine sandstone**, well sorted, angular quartz, volcanic glass, gypsum, moderately consolidated, 1 foot thick, massive, tabular.
- 145. Pale yellowish brown (10YR 6/2) very fine sandstone**, well sorted, angular quartz, volcanic glass, biotite, sanadine, feldspar, gypsum, unconsolidated, 9 feet thick, channel.
- 146. Pale yellowish brown (10YR 6/2) fine sandstone**, well sorted, subrounded quartz, volcanic glass, biotite, sanadine, feldspar, unconsolidated, 4 feet 3 inches thick, channel.
- 147. Very pale orange (10YR 8/2) fine sandstone**, moderately sorted, subrounded quartz, volcanic glass, sanadine, feldspars, gypsum, unconsolidated, 1 foot thick, massive, tabular.
- 148. Yellowish gray (5Y 7/2) medium sandstone**, well sorted, subrounded quartz, volcanic glass, biotite, sanadine, feldspars, gypsum, unconsolidated, 3 feet 10 inches thick, 224 foot wide channel, 1 inch long gypsum crystals.
- 149. Pale yellowish brown (10YR 6/2) fine sandstone**, moderately sorted, subangular quartz, biotite, volcanic glass, feldspar, sanadine, gypsum, poorly consolidated, 3 feet 10 inches thick, massive, tabular.
- 150. Dark yellowish brown (10YR 4/2) clay**, carbon, gypsum, fissile, 3 feet thick, massive, tabular.
- 151. Very pale orange (10YR 8/2) silt**, well sorted, oval, angular quartz, volcanic glass, biotite, muscovite, gypsum, sphene, moderately consolidated, 4 feet 3 inches thick, tabular, massive with cross bedding in top half, tabular, shell hash.
- 152. Light gray (N7) volcanic ash**, rhyolitic, calcite cemented, very fine angular quartz, volcanic glass, biotite, very well consolidated, 10 inches thick, massive, tabular, ripple marks on the surface, shell hash, Peter's Gulch Ash.
- 153. Pale yellowish brown (10YR 6/2) clay**, carbon, shell hash, well consolidated, 9 inches thick, massive, tabular, green-gray in unweathered portion.
- 154. Pale yellowish brown (10YR 6/2) clay**, carbon, shell hash, mollusk shell, well consolidated, 8 inches thick, massive, tabular, gray in unweathered portions.
- 155. Pale yellowish orange (10YR 8/2) clay**, shell hash, well consolidated, 9 inches thick, massive, tabular, 0.5 inch thick basaltic ash layer in the middle of the unit.

- 156. Dark yellowish brown (10YR 4/2) clay**, carbon, gypsum, well consolidated, 1 foot 5 inches thick, massive, tabular, grades upward into a gray clay.
- 157. Pale yellowish brown (10YR 6/2) clay**, carbon, fissile, well consolidated, 7 inches thick, massive, tabular,
- 158. Pale yellowish brown (10YR 6/2) very fine sandstone**, moderately sorted, angular quartz, biotite, volcanic glass, gypsum, moderately consolidated, 3 feet 3 inches thick, massive, tabular, creates 80-90° slopes.
- 159. Moderate brown (5YR 4/4) clay**, carbon, fossil leaves, well consolidated, 1 foot 3 inches thick, massive, tabular.
- 160. Pale yellowish brown (10YR 7/2) fine sandstone**, poorly sorted, subangular quartz, volcanic glass, biotite, gypsum, poorly consolidated, 4 feet 1 inch thick exposed (bottom covered by modern stream sediments, massive, tabular
- 161. Landslide deposits**, 56 feet thick, contains Tuanna Gravel clasts, Yahoo Clay, and Glenn's Ferry material.
- 162. Medium bluish gray (5B 5/1) basalt**, thickness unknown, possible the Banbury Basalt.

APPENDIX C

PETROGRAPHIC DESCRIPTIONS

Fossil Gulch Lithologic Column

TOP OF THE SECTION

1. **Pale brown (5YR 5/2) coarse sandstone**, poorly sorted, subrounded quartz, black lithic particles, calcite cement, poorly consolidated, tabular, 19 inches thick, top formation.
2. **Grayish red (10R 4/2) cobble conglomerate**, very poorly sorted, rounded lithic particles, quartz, biotite, muscovite, calcite cement, very poorly consolidated, channel, 106 inches thick, Tuanna Gravels.
3. **Pale yellowish brown (10YR 6/2) fine sandstone**, well sorted, subangular quartz, biotite, calcite cement, poorly consolidated, tabular, 8.5 inches thick.
4. **Pale brown (5YR 5/2) clay**, sorted, calcite, cement, well consolidated, tabular, 13 inches thick, 10% black organic material resembling leaves.
5. **Very pale orange (10YR 8/2) very coarse siltstone**, very well sorted, subangular quartz, biotite, calcite cement, very poorly consolidated, tabular, 3 inches thick, Ash?.
6. **Pale brown (5YR 5/2) clay**, moderately consolidated, tabular, 7 inches thick, , black organic material, sandy (medium, moderately sorted, quartz, biotite).
7. **Pale yellowish brown (10YR 6/2) coarse siltstone**, well sorted, subangular quartz, biotite, calcite cement, moderately consolidated, tabular, 14 inches thick.
8. **Light brownish gray (5YR 6/1) fine sandstone**, well sorted, subrounded quartz, biotite, calcite cement, moderately consolidated, tabular, 7 inches thick.
9. **Pale yellowish brown (10YR 6/2) very fine sandstone**, well sorted, subangular quartz, black lithic particles, carnotite, calcite cement, poorly consolidated, tabular, 4 inches thick.
10. **Very pale orange (10YR 8/2) fine sandstone**, well sorted, subangular quartz, biotite, black lithic particles, hematite, calcite cement, very well consolidated, tabular, 3 inches thick.
11. **Pale yellowish brown (10YR 6/2) very fine sandstone**, well sorted, subangular quartz, black glass particles, hematite, carnotite, calcite cement, poorly consolidated, tabular, 17 inches thick, cross trough bedding.
12. **Light brown (5YR 6/4) very fine sandstone**, moderately sorted, subangular quartz, black lithic particles, calcite cement, poorly consolidated, tabular, 12 inches thick.
13. **Pale red (10 R 6/2) fine sandstone**, well sorted, subrounded quartz, biotite, black lithic particles, calcite cement, poorly consolidated, tabular, 14 inches thick.
14. **Pale brown (5YR 5/2) medium sandstone**, poorly sorted, subangular quartz, black lithic particles, hematite, calcite cement, very poorly consolidated, channel, 45 inches thick.
15. **Pale brown (5YR 5/2) clay**, very well consolidated, tabular, 7 inches thick.

16. **Grayish orange pink (5YR 7/2) medium siltstone**, well sorted, angular quartz, biotite, black lithic particles, hematite, calcite cement, moderately consolidated, tabular, 12 inches thick.
17. **Blackish red (5R 2/2) clay**, well consolidated, tabular, 10 inches thick, 10% black organic material.
18. **Very pale orange (10YR 8/2) fine sandstone**, moderately sorted, subrounded quartz, biotite, black lithic particles, calcite cement, poorly consolidated, tabular, 20 inches thick.
19. **Yellowish gray (5Y 8/1) rhyolite ash**, sorted, glass, cement, very well consolidated, tabular, 17 inches thick.
20. **Pinkish gray (5YR 8/1) coarse siltstone**, well sorted, angular quartz, biotite, hematite, calcite cement, moderately consolidated, tabular, 12 inches thick, shell hash.
21. **Pale brown (5YR 5/2) clay**, well consolidated, tabular, 25 inches thick, snail shell, shell hash.
22. **Grayish brown (5YR 3/2) clay**, very well consolidated, tabular, 9 inches thick, shell hash.
23. **Pale yellowish brown (10YR 6/2) very coarse siltstone**, well sorted, subangular quartz, black glass, sphene, hematite, carnotite, calcite cement, moderately consolidated, channel, 13 inches thick, erosional bottom surface.
24. **Pale yellowish brown (10YR 6/2) coarse siltstone**, well sorted, angular quartz, biotite, carnotite, calcite cement, poorly consolidated, tabular, 27 inches thick.
25. **Pale yellowish brown (10YR 6/2) clay**, moderately consolidated, lenticular, 60 inches thick, 50% sand, sand lens in middle, 30 feet wide.
26. **Pale yellowish brown (10YR 6/2) very fine sandstone**, well sorted, subangular quartz, black lithic particles, sphene carnotite, calcite cement, poorly consolidated, channel, 18 inches thick, erosional bottom surface.
27. **Pale yellowish brown (10YR 6/2) fine sandstone**, poorly sorted, subrounded quartz, feldspar, lithic particles, muscovite, carnotite, calcite cement, very poorly consolidated, channel, 93 inches thick, cross trough bedding SW.
28. **Pale brown (5YR 5/2) medium sandstone**, poorly sorted, rounded quartz, black lithic particles, calcite cement, very well consolidated, channel, 14 inches thick, currently being quarried for horse bones.
29. **Very pale orange (10YR 8/2) fine sandstone**, poorly sorted, angular quartz, biotite, black lithic particles, hematite, clay cement, very well consolidated, tabular, 7 inches thick.
30. **Pale yellowish brown (10YR 6/2) fine sandstone**, moderately sorted, subangular quartz, feldspar, biotite, black lithic particles, clay cement, well consolidated, tabular, 7 inches thick.
31. **Dark yellowish brown (10YR 4/2) medium sandstone**, moderately sorted, rounded black lithic particles, carnotite, no cement, very poorly consolidated, tabular, 9 inches thick.

32. **Brownish gray (5YR 4/1) medium sandstone**, moderately sorted, subangular quartz, clay, biotite, calcite cement, moderately consolidated, tabular, 10 inches thick, clayey.
33. **Pale yellowish brown (10YR 6/2) fine sandstone**, well sorted, subangular quartz, clay, biotite, black lithic particles, carnotite, calcite cement, poorly consolidated, tabular, 28 inches thick.
34. **Pale brown (5YR 5/2) very fine sandstone**, moderately sorted, subrounded quartz, black lithic particles, calcite cement, poorly consolidated, tabular, 22 inches thick.
35. **Pale brown (5YR 5/2) clay**, calcite cement, moderately consolidated, tabular, 8 inches thick, sandy (fine, well sorted, angular quartz).
36. **Very pale orange (10YR 8/2) clay**, calcite cement, moderately consolidated, tabular, 2 inches thick.
37. **Pale brown (5YR 5/2) clay**, calcite cement, moderately consolidated, tabular, 5 inches thick, sandy (medium, moderately sorted, subrounded quartz).
38. **Dark yellowish brown (10YR 4/2) clay**, calcite cement, well consolidated, tabular, 4 inches thick.
39. **Pale brown (5YR 5/2) clay**, calcite cement, moderately consolidated, tabular, 8 inches thick, biotite.
40. **Moderate yellowish brown (10YR 5/4) medium sandstone**, poorly sorted, subangular quartz, black lithic particles, carnotite, clay, calcite cement, moderately consolidated, tabular, 28 inches thick, clayey.
41. **Pale yellowish brown (10YR 6/2) fine sandstone**, well sorted, angular quartz, lithic particles, calcite cement, poorly consolidated, tabular, 23 inches thick.
42. **Pale yellowish brown (10YR 6/2) medium sandstone**, moderately sorted, subangular quartz, biotite, calcite cement, poorly consolidated, tabular, 10 inches thick.
43. **Grayish orange pink (5YR 7/2) very fine sandstone**, well sorted, angular quartz, biotite, calcite cement, moderately consolidated, tabular, 11 inches thick.
44. **Pale yellowish brown (10YR 6/2) clay**, calcite cement, poorly consolidated, tabular, 5 inches thick, silty (coarse, well sorted, angular quartz).
45. **Pale yellowish brown (10YR 6/2) fine sandstone**, moderately sorted, subangular quartz, biotite, calcite cement, poorly consolidated, tabular, 12 inches thick.
46. **Pale yellowish brown (10YR 6/2) clay**, calcite cement, well consolidated, tabular, 9 inches thick, sandy (fine, well sorted, subangular quartz).
47. **Moderate yellowish brown (10YR 4/2) fine sandstone**, well sorted, subrounded quartz, biotite, hematite, calcite cement, poorly consolidated, tabular, 8 inches thick.
48. **Grayish orange (10YR 7/4) very fine sandstone**, well sorted, angular quartz, biotite, hematite, calcite cement, poorly consolidated, tabular, 26 inches thick.

49. **Pale brown (5YR 5/2) clay**, calcite cement, poorly consolidated, tabular, 15 inches thick, silty (coarse, angular quartz).
50. **Moderate yellowish brown (10YR 4/2) clay**, calcite cement, well consolidated, tabular, 9 inches thick, silty (coarse, well sorted, angular quartz, biotite, black lithic particles).
51. **Moderate yellowish brown (10YR 4/2) coarse siltstone**, moderately sorted, subangular quartz, clay, biotite, hematite, calcite cement, moderately consolidated, tabular, 8 inches thick, clayey.
52. **Moderate yellowish brown (10 5/4) clay**, calcite cement, poorly consolidated, tabular, 10 inches thick, silty (medium, moderately sorted, angular quartz, hematite).
53. **Dark yellowish brown (10YR 4/2) medium sandstone**, moderately sorted, subangular quartz, biotite, hematite, calcite cement, poorly consolidated, tabular, 6 inches thick.
54. **Grayish orange (10YR 7/4) very fine sandstone**, well sorted, subangular quartz, black lithic particles, hematite, calcite cement, poorly consolidated, , channel , 34 inches thick.
55. **Pale yellowish brown (10YR 6/2) very coarse siltstone**, well sorted, angular quartz, biotite, hematite, calcite cement, well consolidated, tabular, 14 inches thick, bottom bioturbated.
56. **Grayish brown (5YR 3/2) clay**, calcite cement, moderately consolidated, tabular, 23 inches thick, bioturbated, gradational contact with #55.
57. **Pale yellowish brown (10YR 6/2) coarse siltstone**, moderately sorted, subangular quartz, clay, biotite, carnotite, calcite cement, poorly consolidated, tabular, 11 inches thick, clayey.
58. **Pale yellowish brown (10YR 6/2) very fine sandstone**, well sorted, subangular quartz, biotite, garnet, calcite cement, poorly consolidated, tabular, 9 inches thick.
59. **Pale yellowish brown (10YR 6/2) fine sandstone**, moderately sorted, subangular quartz, biotite, black lithic particles, garnet, calcite cement, poorly consolidated, tabular, 10 inches thick.
60. **Grayish orange (10YR 7/4) coarse siltstone**, well sorted, angular quartz, biotite, hematite, calcite cement, moderately consolidated, tabular, 11 inches thick.
61. **Moderate yellowish brown (10YR 5/4) coarse sandstone**, moderately sorted, rounded quartz, biotite, black lithic particles, hematite, no cement, very poorly consolidated, tabular, 16 inches thick.
62. **Pale yellowish brown (10YR 6/2) very fine sandstone**, well sorted, subangular quartz, biotite, black lithic particles, calcite cement, poorly consolidated, tabular, 16 inches thick.
63. **Moderate yellowish brown (10YR 5/4) medium sandstone**, moderately sorted, subrounded quartz, biotite, hematite, calcite cement, poorly consolidated, tabular, 44 inches thick.
64. **Yellowish gray (5Y 7/2) coarse siltstone**, well sorted, subangular quartz, biotite, calcite cement, moderately consolidated, tabular, 8 inches thick.

65. **Yellowish brown (10YR 5/4) very fine sandstone**, moderately sorted, subrounded quartz, biotite, black lithic particles, calcite cement, poorly consolidated, tabular, 10 inches thick.
66. **Pale yellowish brown (10YR 6/2) very fine sandstone**, moderately sorted, subrounded quartz, biotite, hematite, calcite cement, moderately consolidated, tabular, 16 inches thick.
67. **Dark yellowish brown (10YR 4/2) coarse sandstone**, moderately sorted, subrounded quartz, biotite, black lithic particles, calcite cement, poorly consolidated, tabular, 16 inches thick.
68. **Pale yellowish brown (10YR 6/2) very fine sandstone**, well sorted, subrounded quartz, biotite, hematite, calcite cement, very poorly consolidated, tabular, 8 inches thick.
69. **Pale yellowish brown (10YR 6/2) fine sandstone**, well sorted, subangular quartz, biotite, hematite, calcite cement, very poorly consolidated, tabular, 12 inches thick.
70. **Pale yellowish brown (10YR 6/2) clay, calcite cement**, moderately consolidated, tabular, 8 inches thick, silty (very coarse, moderately sorted, subangular quartz, black lithic particles, biotite).
71. **Dark yellowish brown (10YR 4/2) medium sandstone**, poorly sorted, rounded quartz, black lithic particles, biotite, calcite cement, very poorly consolidated, tabular, 7 inches thick.
72. **Grayish orange (10YR 7/4) coarse siltstone**, well sorted, subangular quartz, biotite, calcite cement, poorly consolidated, tabular, 11 inches thick.
73. **Moderate yellowish brown (10YR 5/4) very fine sandstone**, well sorted, subangular quartz, biotite, muscovite, calcite cement, poorly consolidated, tabular, 5 inches thick.
74. **Moderate olive brown (5Y 4/4) clay**, calcite cement, moderately consolidated, tabular, 12 inches thick, silty (coarse, well sorted, angular quartz, biotite, hematite).
75. **Dark yellowish brown (10YR 4/2) clay**, calcite cement, moderately consolidated, tabular, 10 inches thick.
76. **Pale yellowish brown (10YR 6/2) medium sandstone**, moderately sorted, subrounded quartz, clay, biotite, black lithic particles, calcite cement, poorly consolidated, tabular, 12 inches thick, clayey, clumps.
77. **Moderately yellowish brown (10YR 5/4) very fine sandstone**, moderately sorted, subangular quartz, black lithic particles, biotite, hematite, calcite cement, poorly consolidated, tabular, 12 inches thick, clay clumps.
78. **Moderate olive brown (5Y 4/4) medium sandstone**, moderately sorted, subangular quartz, biotite, black lithic particles, calcite cement, very poorly consolidated, tabular, 20 inches thick.
79. **Pale yellowish brown (10YR 6/2) very fine sandstone**, well sorted, angular quartz, biotite, black lithic particles, apatite, calcite cement, very poorly consolidated, tabular, 7 inches thick.
80. **Light olive brown (5Y 5/6) medium sandstone**, moderately sorted, subangular quartz, biotite, hematite, no cement, very poorly consolidated, tabular, 20 inches thick.

81. **Pale yellowish brown (10YR 6/2) very fine sandstone**, well sorted, angular quartz, biotite, black lithic particles, calcite cement, poorly consolidated, tabular, 9 inches thick.
82. **Very pale orange (10YR 8/2) very coarse siltstone**, well sorted, subangular quartz, biotite, black lithic particles, calcite cement, very well consolidated, tabular, 2 inches thick, calcrete.
83. **Pale yellowish brown (10YR 6/2) very coarse siltstone**, well sorted, subangular quartz, biotite, black lithic particles, calcite cement, poorly consolidated, tabular, 13 inches thick.
84. **Pale yellowish brown (10YR 6/2) very coarse siltstone**, moderately sorted, subrounded quartz, biotite, black lithic particles, calcite cement, poorly consolidated, tabular, 10 inches thick.
85. **Pale yellowish brown (10YR 6/2) very coarse siltstone**, well sorted, angular quartz, biotite, black lithic particles, calcite cement, moderately consolidated, lenticular, 18 inches thick.
86. **Pale yellowish brown (10YR 6/2) medium sandstone**, moderately sorted, subrounded quartz, black lithic particles, biotite, calcite cement, moderately consolidated, lenticular, 8 inches thick.
87. **Moderate yellowish brown (10YR 5/4) fine sandstone**, moderately sorted, subangular quartz, biotite, black lithic particles, hematite, calcite cement, very poorly consolidated, lenticular, 8 inches thick.
88. **Pale yellowish brown (10YR 6/2) very coarse siltstone**, well sorted, angular quartz, black lithic particles, biotite, calcite cement, poorly consolidated, lenticular, 19 inches thick.
89. **Dark yellowish brown (10YR 4/2) clay**, moderately consolidated, tabular, 15 inches thick, silty (very coarse, well sorted, angular quartz).
90. **Yellowish gray (5Y 7/2) coarse siltstone**, well sorted, subangular quartz, black lithic particles, biotite, gold, calcite cement, poorly consolidated, lenticular, 18 inches thick.
91. **Pale yellowish brown (10YR 6/2) fine sandstone**, well sorted, subrounded quartz, black lithic particles, biotite, hematite, calcite cement, very poorly consolidated, lenticular, 16 inches thick, carnotite.
92. **Grayish orange (10YR 7/4) very coarse siltstone**, well sorted, subangular quartz, biotite, black lithic particles, carnotite, calcite cement, moderately consolidated, tabular, 27 inches thick.
93. **Dark yellowish brown (10YR 4/2) clay**, moderately consolidated, tabular, 9 inches thick, friable, silty (well sorted, subrounded quartz).
94. **Pale yellowish brown (10YR 6/2) medium sandstone**, well sorted, subrounded quartz, black lithic particles, biotite, clay, calcite cement, poorly consolidated, tabular, 10 inches thick.
95. **Dark yellowish orange (10YR 6/6) fine sandstone**, well sorted, subangular quartz, biotite, black lithic particles, carnotite, calcite cement, moderately consolidated, lenticular, 47 inches thick, channel.

96. **Dark yellowish brown (10YR 4/2) medium sandstone**, well sorted, subangular quartz, clay, biotite, calcite cement, poorly consolidated, tabular, 32 inches thick, channel.
97. **Pale yellowish brown (10YR 6/2) very fine sandstone**, well sorted, subangular quartz, biotite, black lithic particles, calcite cement, poorly consolidated, tabular, 37 inches thick, calcrete nodules.
98. **Pale brown (5YR 5/2) fine sandstone**, well sorted, subangular quartz, biotite, hematite, calcite cement, poorly consolidated, channel, 35 inches thick.
99. **Pale yellowish brown (10YR 6/2) coarse siltstone**, well sorted, angular quartz, biotite, hematite, calcite cement, moderately consolidated, tabular, 76 inches thick.
100. **Very pale orange (10YR 8/2) coarse siltstone**, well sorted, angular quartz, biotite, hematite, calcite cement, well consolidated, tabular, 19 inches thick.
101. **Pale yellowish brown (10YR 6/2) clay**, calcite cement, moderately consolidated, tabular, 11 inches thick, friable silty (medium, well sorted, angular quartz, biotite).
102. **Moderate yellowish brown (10YR 5/4) clay**, calcite cement, moderately consolidated, tabular, 18 inches thick, friable, silty (coarse, well sorted, angular quartz, biotite),.
103. **Dark yellowish brown (10YR 4/2) clay**, calcite cement, moderately consolidated, tabular, 19 inches thick, friable, sandy (fine, well sorted, subangular black lithic particles, carnotite).
104. **Very pale orange (10YR 8/2) very coarse silt**, well sorted, angular quartz,, black lithic particles, carnotite, calcite cement, very well consolidated, tabular, 7 inches thick.
105. **Moderate yellowish brown (10YR 4/2) clay**, moderately consolidated, tabular, 18 inches thick, friable, sandy (medium, moderately sorted, subrounded quartz, biotite, hematite).
106. **Pale yellowish brown (10YR 6/2) very fine sandstone**, well sorted, subangular quartz, biotite, carnotite, calcite cement, well consolidated, tabular, 7 inches thick.
107. **Moderate yellowish brown (10YR 5/4) medium sandstone**, moderately sorted, subrounded quartz, biotite, black lithic particles, calcite cement, very poorly consolidated, tabular, 19 inches thick.
108. **Moderate yellowish brown (10YR 5/4) fine sandstone**, moderately sorted, subangular quartz, black lithic particles, biotite, carnotite, hematite, calcite cement, very poorly consolidated, lenticular, 20 inches thick, cemented cross trough bedding, S 20 W.
109. **Grayish brown (5YR 3/2) medium sandstone**, well sorted, subrounded quartz, black lithic particles, biotite, hematite, sphene, no cement, very poorly consolidated, lenticular, 26 inches thick.
110. **Dark yellowish brown (10YR 4/2) medium sandstone**, well sorted, subangular quartz, black lithic particles, carnotite, gold, no cement, very poorly consolidated, channel, 170 inches thick, 284 ft wide, calcrete nodules up to 3 ft.
111. **Grayish orange (10YR 7/4) very coarse siltstone**, well sorted, subangular quartz, black lithic particles, hematite, carnotite, calcite cement, poorly consolidated, tabular, 21 inches thick.

- 112. Very pale orange (10YR 8/2) medium siltstone**, well sorted, angular quartz, biotite, black glass, calcite cement, well consolidated, tabular, 13 inches thick.
- 113. Dark yellowish brown (10YR 4/2) clay**, calcite cement, moderately consolidated, lenticular, 5 inches thick, friable, silty (coarse, angular quartz).
- 114. Grayish orange (10YR 7/4) medium siltstone**, well sorted, subangular quartz, biotite, no cement, very poorly consolidated, tabular, 20 inches thick.
- 115. Moderate yellowish brown (10YR 5/4) fine sandstone**, well sorted, subrounded quartz, biotite, hematite, carnotite, no cement, very poorly consolidated, channel, 108 inches thick.
- 116. Very pale orange (10YR 8/2) fine siltstone**, well sorted, angular quartz, biotite, hematite, unknown cement, well consolidated, tabular, 4 inches thick, possible ash.
- 117. Grayish orange (10YR 7/4) medium siltstone**, well sorted, subangular quartz, biotite, unknown cement, moderately consolidated, tabular, 17 inches thick.
- 118. Grayish orange (10YR 7/4) very fine sandstone**, well sorted, angular quartz, black lithic particles, no cement, very poorly consolidated, tabular, 4 inches thick.
- 119. Grayish red (10R 4/2) fine sandstone**, moderately sorted, subrounded black lithic particles, fine gypsum crystals, feldspars, unknown cement, moderately consolidated, tabular, 5 inches thick, Top of Carbonaceous Shale Facies.
- 120. Moderately yellowish brown (10YR 5/4) very coarse siltstone**, moderately sorted, subangular quartz, biotite, black lithic particles, unknown cement, poorly consolidated, tabular, 9 inches thick.
- 121. Grayish orange (10YR 7/4) very coarse siltstone**, well sorted, angular quartz, biotite, black lithic particles, hematite, unknown cement, moderately consolidated, tabular, 20 inches thick.
- 122. Moderate orange pink (10R 7/4) shale**, well consolidated, tabular, 11 inches thick, diatomaceous, black organic material, leaf imprints (grass).
- 123. Pale yellowish brown (10YR 6/2) medium siltstone**, moderately sorted, subangular quartz, biotite, unknown cement, moderately consolidated, tabular, 6 inches thick.
- 124. Pale brown (5YR 5/2) clay**, moderately consolidated, tabular, 4 inches thick, friable.
- 125. Pale yellowish brown (10YR 6/2) very fine sandstone**, moderately sorted, subangular quartz, biotite, lithic particles, no cement, poorly consolidated, tabular, 5 inches thick.
- 126. Grayish red (5R 4/2) shale**, well consolidated, tabular, 6 inches thick, diatomaceous, black organic material, leaf imprints, gypsum.
- 127. Light brownish gray (5YR 6/1) medium siltstone**, well sorted, angular quartz, biotite, hematite, no cement, very poorly consolidated, channel, 3 inches thick.

- 128. Dark yellowish brown (10YR 4/2) medium sandstone**, poorly sorted, rounded quartz, biotite, lithic particles, fine gypsum crystals, unknown cement, poorly consolidated, tabular, 5 inches thick, top 2 inches full of black organic material.
- 129. Pale red (10R 6/2) shale**, cement, well consolidated, tabular, 7 inches thick, diatomaceous, black organic material, gypsum crystals, gypsum crystals,.
- 130. Light brown (5YR 6/4) very fine sandstone**, well sorted, angular quartz, biotite, fine gypsum crystals, unknown cement, poorly consolidated, tabular, 6 inches thick.
- 131. Dark yellowish brown (10YR 4/2) clay**, moderately consolidated, tabular, 15 inches thick, friable, silty (medium, well sorted, angular quartz, carnotite).
- 132. Moderate yellowish brown (10YR 5/4) clay**, moderately consolidated, tabular, 3 inches thick, friable, silty (medium, well sorted, angular quartz, carnotite).
- 133. Grayish orange (10YR 7/4) very fine sandstone**, moderately sorted, subangular quartz, biotite, black lithic particles, hematite, gypsum, unknown cement, poorly consolidated, tabular, 2 inches thick.
- 134. Moderate brown (5YR 4/4) very coarse siltstone**, well sorted, angular quartz, biotite, clay, unknown cement, poorly consolidated, tabular, 4 inches thick, .
- 135. Brownish black (5YR 2/1) coarse volcanic ash**, well sorted, angular black glass, hematite, gypsum, no cement, very well consolidated, tabular, 13 inches thick, 3.2 m.y. marker bed.
- 136. Pale reddish brown (10R 5/4) shale**, well consolidated, tabular, 15 inches thick, diatomaceous, black organic material, fine gypsum crystals, flaky.
- 137. Grayish orange (10YR 7/4) very fine sandstone**, well sorted, subangular quartz, biotite, gypsum, unknown cement, poorly consolidated, tabular, 3 inches thick.
- 138. Moderate yellowish brown (10YR 5/4) very fine sandstone**, well sorted, angular quartz, biotite, hematite, unknown cement, poorly consolidated, tabular, 16 inches thick.
- 139. Pale reddish brown (10R 5/4) shale**, well consolidated, tabular, 21 inches thick, diatomaceous, flaky, black organic matter, leaf imprints, carnotite, gypsum.
- 140. Moderate yellowish brown (10YR 5/4) very coarse siltstone**, well sorted, subangular quartz, black lithic particles, biotite, carnotite, gypsum, unknown cement, poorly consolidated, tabular, 13 inches thick, bottom of Carbonaceous Shale.
- 141. Moderate yellowish brown (10YR 5/4) fine sandstone**, moderately sorted, subangular quartz, quartz, carnotite, biotite, black lithic particles, unknown cement, well consolidated, tabular, 13 inches thick.
- 142. Yellowish gray (5Y 7/2) very fine sandstone**, well sorted, angular quartz, biotite, carnotite, hematite, no cement, very poorly consolidated, tabular, 11 inches thick.
- 143. Moderate yellowish brown (10 YR 5/4) clay**, very well consolidated, tabular, 17 inches thick, goethite nodules, organic matter, bioturbated, insect(?), silty (coarse, well sorted, subangular quartz), gypsum.

- 144. Moderate brown (5YR 4/4) shale**, very well consolidated, tabular, 11 inches thick, diatomaceous, black organic material, gypsum, hematite.
- 145. Moderate yellowish brown (10YR 5/4) fine sandstone**, well sorted, subangular quartz, biotite, hematite, black lithic particles, unknown cement, poorly consolidated, tabular, 10 inches thick.
- 146. Moderate yellowish brown (10YR 5/4) very coarse siltstone**, well sorted, angular quartz, black lithic particles, biotite, gypsum, hematite, unknown cement, poorly consolidated, tabular, 17 inches thick.
- 147. Moderate yellowish brown (10YR 5/4) medium sandstone**, well sorted, subrounded quartz, black lithic particles, hematite, gypsum, unknown cement, very poorly consolidated, channel, 101 inches thick.
- 148. Moderate yellowish brown (10YR 5/4) very fine sandstone**, moderately sorted, subangular quartz, black glass, biotite, hematite, unknown cement, very poorly consolidated, tabular, 36 inches thick.
- 149. Very pale orange (10YR 8/2) coarse siltstone**, well sorted, angular quartz, black lithic particles, biotite, calcite cement, moderately consolidated, tabular, 19 inches thick.
- 150. Dusky brown (5YR 2/2) clay**, well consolidated, tabular, 16 inches thick, friable.
- 151. Dark yellowish brown (10YR 4/2) clay**, calcite cement, well consolidated, tabular, 8 inches thick, friable.
- 152. Very pale orange (10YR 8/2) very fine sandstone**, well sorted, subrounded quartz, biotite, calcite cement, moderately consolidated, tabular, thickness not measured. Bottom of measured section.

APPENDIX D

PETROGRAPHIC DESCRIPTIONS

Bald Knob Lithologic Column

Top of Column

1. **Pale brown (5YR 5/2) coarse sandstone**, poorly sorted, rounded quartz, calcite cement, poorly consolidated, tabular, 45 inches thick, top of stratigraphic column.
2. **Grayish red (10R 4/2) cobble conglomerate**, very poorly sorted, rounded black lithic particles, quartz, biotite, muscovite, calcite cement, very poorly consolidated, channel, 57 inches thick, Tuana Gravels.
3. **Pale yellowish brown (10YR 6/2) fine sandstone**, well sorted, angular quartz, black lithic particles, no cement, poorly consolidated, tabular, 32 inches thick.
4. **Pale yellowish brown (10YR 6/2) clay**, moderately consolidated, tabular, 11 inches thick, friable, sandy (very fine, moderately sorted, angular quartz, biotite).
5. **Pale yellowish brown (10YR 6/2) clay**, moderately consolidated, tabular, 10 inches thick, friable, silty (very coarse, well sorted, subangular quartz, biotite).
6. **Dark yellowish brown (10YR 4/2) fine sandstone**, moderately sorted, subrounded quartz, black lithic particles, no cement, moderately consolidated, tabular, 3 inches thick, friable.
7. **Light olive gray (5Y 5/2) clay**, moderately consolidated, tabular, 7 inches thick, friable.
8. **Pale brown (5YR 5/2) clay**, moderately consolidated, tabular, 6 inches thick, sandy (fine, moderately sorted, subangular quartz, black lithic particles).
9. **Pale yellowish brown (10YR 6/2) clay**, moderately consolidated, tabular, 18 inches thick, friable, shell hash.
10. **Pale brown (5YR 5/2) very fine sandstone**, moderately sorted, subangular quartz, black lithic particles, calcite cement, poorly consolidated, tabular, 3 inches thick.
11. **Pale yellowish brown (10YR 6/2) clay**, moderately consolidated, tabular, 3 inches thick, friable, sandy (fine, well sorted, subangular quartz), calcite.
12. **Grayish orange pink (10R 8/2) medium sandstone**, well sorted, angular quartz, black lithic particles, calcite cement, well consolidated, tabular, 7 inches thick, 75% calcite, "calcrete".
13. **Yellowish gray (5Y 8/1) very coarse siltstone**, well sorted, subangular quartz, calcite cement, moderately consolidated, channel, 3 inches thick, Bottom eroded into lower unit.
14. **Pale yellowish brown (10YR 6/2) very fine sandstone**, well sorted, subangular quartz, biotite, calcite cement, moderately consolidated, tabular, 5 inches thick.
15. **Pale brown (5Y 5/2) coarse siltstone**, well sorted, subangular quartz, biotite, calcite cement, poorly consolidated, tabular, 3 inches thick.
16. **Pale yellowish brown (10YR 6/2) very fine sandstone**, well sorted, subangular quartz, biotite, calcite cement, poorly consolidated, tabular, 25 inches thick.
17. **Olive gray (5Y 3/2) clay**, moderately consolidated, tabular, 6 inches thick, friable.

18. **Moderate olive brown (5Y 4/4) clay**, moderately consolidated, tabular, 4 inches thick, friable.
19. **Yellowish gray (5Y 7/2) coarse siltstone**, well sorted, subangular quartz, calcite cement, very well consolidated, tabular, 3 inches thick.
20. **Pale yellowish brown (10YR 6/2) coarse siltstone**, well sorted, subrounded quartz, black lithic particles, calcite cement, poorly consolidated, tabular, 3 inches thick.
21. **Grayish orange pink (5YR 7/2) very fine sandstone**, well sorted, subrounded quartz, black lithic particles, calcite cement, very well consolidated, tabular, 2 inches thick.
22. **Grayish orange pink (5YR 7/2) very fine sandstone**, well sorted, subrounded quartz, black lithic particles, calcite cement, very poorly consolidated, tabular, 3 inches thick.
23. **Grayish orange pink (5YR 7/2) fine sandstone**, well sorted, subrounded quartz, black lithic particles, calcite cement, very well consolidated, tabular, 2 inches thick.
24. **Very pale orange (10YR 8/2) very fine sandstone**, well sorted, subangular quartz, black lithic particles, calcite cement, very poorly consolidated, tabular, 4 inches thick, 1 inch wide well consolidated nodules.
25. **Very pale orange (10YR 8/2) very coarse siltstone**, well sorted, angular quartz, black lithic particles, calcite cement, very well consolidated, tabular, 2 inches thick.
26. **Very pale orange (10YR 8/2) very coarse siltstone**, moderately sorted, angular quartz, black lithic particles, calcite cement, poorly consolidated, tabular, 5 inches thick.
27. **Dusky yellowish brown (10YR 2/2) clay**, well consolidated, tabular, 8 inches thick, silty (coarse, moderately sorted, subangular quartz, black lithic particle).
28. **Pale yellowish brown (10YR 6/2) coarse siltstone**, well sorted, angular quartz, calcite cement, poorly consolidated, tabular, 54 inches thick.
29. **Pale yellowish brown (10YR 6/2) coarse siltstone**, well sorted, angular quartz, black lithic particles, calcite cement, very well consolidated, tabular, 1 inch thick.
30. **Grayish orange pink (5YR 7/1) coarse siltstone**, calcite cement, very poorly consolidated, tabular, 19 inches thick.
31. **Very pale orange (10YR 8/2) medium siltstone**, well sorted, subangular quartz, calcite cement, very well consolidated, tabular, 2 inches thick.
32. **Pale yellowish brown (10YR 6/2) fine sandstone**, moderately sorted, subrounded quartz, black lithic particles, calcite cement, poorly consolidated, tabular, 16 inches thick.
33. **Pale yellowish brown (10YR 6/2) medium sandstone**, moderately sorted, subangular quartz, black glass, calcite cement, moderately consolidated, tabular, 9 inches thick, white streaks of calcite.
34. **Pale yellowish brown (10YR 6/2) very coarse siltstone**, moderately sorted, subangular quartz, black lithic particles, calcite cement, poorly consolidated, tabular, 13 inches thick.
35. **Pale yellowish brown (10YR 6/2) coarse siltstone**, well sorted, subangular quartz, black lithic particles, calcite cement, very well consolidated, tabular, 2 inches thick.

36. **Pale brown (5YR 5/2) medium sandstone**, moderately sorted, subrounded quartz, black lithic particles, calcite cement, very poorly consolidated, tabular, 32 inches thick.
37. **Pale brown (5YR 5/2) medium sandstone**, bimodal, subrounded quartz, black lithic particles, hematite, calcite cement, poorly consolidated, tabular, 38 inches thick, 0.5 inch calcrete nodules.
38. **Pale yellowish brown (10YR 6/2) clay**, poorly consolidated, tabular, 17 inches thick, sandy (fine, moderately sorted, angular quartz), calcite.
39. **Pale yellowish brown (10YR 6/2) medium sandstone**, well sorted, subangular quartz, black lithic particles, calcite cement, poorly consolidated, tabular, 7 inches thick, streaks of white calcite.
40. **Moderate yellowish brown (10YR 5/4) fine sandstone**, moderately sorted, angular quartz, biotite, calcite cement, poorly consolidated, tabular, 35 inches thick.
41. **Grayish brown (5YR 3/2) medium sandstone**, moderately sorted, subangular quartz, black lithic particles, hematite, calcite cement, poorly consolidated, tabular, 33 inches thick.
42. **Moderate yellowish brown (10YR 5/4) medium sandstone**, moderately sorted, subrounded quartz, black lithic particles, hematite, calcite cement, poorly consolidated, tabular, 33 inches thick.
43. **Pale brown (5YR 5/2) fine sandstone**, well sorted, subangular quartz, black lithic particles, hematite, calcite cement, moderately consolidated, tabular, 14 inches thick.
44. **Pale yellowish brown (10YR 6/2) very fine sandstone**, moderately sorted, subrounded quartz, biotite, black lithic particles, hematite, calcite cement, poorly consolidated, tabular, 10 inches thick.
45. **Dark yellowish brown (10YR 4/2) fine sandstone**, moderately sorted, subrounded quartz, biotite, hematite, calcite cement, moderately consolidated, tabular, 7 inches thick.
46. **Pale yellowish brown (10YR 6/2) fine sandstone**, moderately sorted, subrounded quartz, goethite, hematite, calcite cement, poorly consolidated, tabular, 13 inches thick.
47. **Pale brown (5YR 5/2) very fine sandstone**, moderately sorted, subangular quartz, black lithic particles, hematite, calcite cement, moderately consolidated, tabular, 18 inches thick.
48. **Pale yellowish brown (10YR 6/2) medium sandstone**, well sorted, subrounded quartz, black lithic particles, hematite, calcite cement, moderately consolidated, tabular, 5 inches thick.
49. **Pale yellowish brown (10YR 6/2) fine sandstone**, well sorted, angular quartz, biotite, hematite, calcite cement, poorly consolidated, tabular, 33 inches thick.
50. **Pale brown (5YR 5/2) fine sandstone**, moderately sorted, subangular quartz, biotite, black lithic particles, hematite, calcite cement, poorly consolidated, tabular, 7 inches thick.
51. **Pale brown (5YR 5/2) fine sandstone**, well sorted, subangular quartz, biotite, black lithic particles, hematite, calcite cement, moderately consolidated, tabular, 49 inches thick.
52. **Pale brown (5YR 5/2) medium siltstone**, well sorted, subrounded quartz, biotite, muscovite, black lithic particles, carnotite, calcite cement, well consolidated, tabular, 17 inches thick.

53. **Dark yellowish brown (10YR 4/2) fine sandstone**, well sorted, subrounded quartz, black lithic particles, carnotite, hematite, calcite cement, poorly consolidated, channel, 61 inches thick, channel outlined by vegetation.
54. **Pale yellowish brown (10YR 6/2) very fine sandstone**, well sorted, subrounded quartz, biotite, calcite cement, poorly consolidated, tabular, 14 inches thick.
55. **Pale brown (5YR 5/2) very coarse siltstone**, well sorted, subrounded quartz, biotite, calcite cement, moderately consolidated, tabular, 5 inches thick.
56. **Pale brown (5YR 5/2) fine sandstone**, well sorted, subrounded quartz, biotite, black lithic particles, calcite cement, moderately consolidated, tabular, 10 inches thick.
57. **Pale yellowish brown (10 6/2) coarse sandstone**, poorly sorted, subrounded quartz, feldspars, biotite, garnet, black lithic particles, calcite cement, moderately consolidated, channel, 284 inches thick, channel delineated by vegetation.
58. **Pale brown (5YR 5/2) medium sandstone**, poorly sorted, rounded quartz, feldspar, biotite, black lithic particles, calcite cement, poorly consolidated, channel, 294 inches thick, channel delineated by vegetation.
59. **Pale yellowish brown (10YR 6/2) very fine sandstone**, moderately sorted, subangular quartz, biotite, calcite cement, poorly consolidated, tabular, 44 inches thick.
60. **Pale yellowish brown (10YR 6/2) medium sandstone**, moderately sorted, subangular quartz, black lithic particles, muscovite, biotite, calcite cement, very poorly consolidated, tabular, 42 inches thick.
61. **Yellowish gray (5Y 5/2) coarse siltstone**, moderately sorted, angular quartz, biotite, calcite cement, moderately consolidated, massive, 33 inches thick.
62. **Dark yellowish brown (10YR 4/2) clay**, well consolidated, tabular, 10 inches thick, friable.
63. **Yellowish gray (5Y 7/2) coarse siltstone**, moderately sorted, subangular quartz, biotite, calcite cement, moderately consolidated, tabular, 41 inches thick.
64. **Dusky yellowish brown (10YR 2/2) clay**, moderately consolidated, tabular, 17 inches thick, silty (coarse, moderately sorted, angular quartz), black organic material, calcite.
65. **Yellowish gray (5Y 7/2) clay**, moderately consolidated, tabular, 19 inches thick, silty (very coarse, well sorted, subangular quartz), friable.
66. **Dusky yellowish brown (10YR 2/2) clay**, well consolidated, tabular, 15 inches thick, friable, silty (coarse, well sorted, angular quartz).
67. **Pale yellowish brown (10YR 6/2) very fine sandstone**, well sorted, subangular quartz, calcite cement, very poorly consolidated, tabular, 12 inches thick.
68. **Pale yellowish brown (10YR 6/2) fine sandstone**, well sorted, angular quartz, biotite, calcite cement, very well consolidated, tabular, 6 inches thick.
69. **Pale yellowish brown (10YR 6/2) fine sandstone**, well sorted, angular quartz, black lithic particles, calcite cement, very poorly consolidated, tabular, 30 inches thick.

70. **Yellowish gray (5Y 8/1) coarse siltstone**, well sorted, angular quartz, biotite, calcite cement, very poorly consolidated, tabular, 44 inches thick.
71. **Pale yellowish brown (10YR 6/2) clay**, moderately consolidated, tabular, 15 inches thick, silty (coarse, well sorted, subangular quartz, black lithic particles), fish scales, calcite.
72. **Grayish orange (10YR 7/4) clay**, very well consolidated, tabular, 37 inches thick.
73. **Yellowish gray (5Y 8/1) coarse siltstone**, well sorted, subrounded quartz, biotite, calcite cement, very well consolidated, channel, 2 inches thick, load forms on bottom.
74. **Pale yellowish brown (10YR 6/2) fine sandstone**, moderately sorted, angular quartz, black lithic particles, calcite cement, very well consolidated, channel, 30 inches thick.
75. **Yellowish gray (5Y 7/2) fine sandstone**, well sorted, subangular quartz, biotite, no cement, very poorly consolidated, channel, 28 inches thick.
76. **Yellowish gray (5Y 7/2) coarse siltstone**, well sorted, angular quartz, biotite, no cement, poorly consolidated, channel, 11 inches thick.
77. **Pale olive (10Y 6/2) medium sandstone**, well sorted, subangular quartz, biotite, black glass, sphene, no cement, very poorly consolidated, channel, 56 inches thick, 25 feet width exposed.
78. **Light olive brown (5Y 5/6) clay**, poorly consolidated, tabular, 49 inches thick, friable, calcite fragments, silty (medium, well sorted, angular, quartz).
79. **Pale olive (10Y 6/2) fine sandstone**, well sorted, subrounded quartz, black lithic particles, no cement, very poorly consolidated, tabular, 10 inches thick.
80. **Yellowish gray (5Y 7/2) medium siltstone**, well sorted, angular quartz, black glass, no cement, very poorly consolidated, tabular, 6 inches thick.
81. **Light olive gray (5Y 5/2) coarse sandstone**, moderately sorted, rounded quartz, feldspar, black glass, biotite, no cement, very poorly consolidated, tabular, 1 inches thick.
82. **Grayish orange (10YR 7/4) coarse sandstone**, bimodal, rounded quartz, black lithic particles, biotite, calcite cement, poorly consolidated, tabular, 3 inches thick, silty (coarse, well sorted, angular quartz).
83. **Pale yellowish brown (10YR 6/2) fine sandstone**, well sorted, subangular quartz, feldspars, black lithic particles, calcite cement, poorly consolidated, channel, 12 inches thick, cross trough bedding at top, East.
84. **Pale yellowish brown (10YR 6/2) coarse sandstone**, moderately sorted, subrounded quartz, black glass, feldspar, garnet, gold, calcite cement, very poorly consolidated, channel, 55 inches thick, grades upward to very fine sand, 3.6 mm fossil bone, 1 inch clay clasts, shell hash, 70 ft wide.
85. **Moderate yellowish brown (10YR 4/2) medium sandstone**, bimodal sorted, angular quartz, black lithic particles, no cement, very poorly consolidated, tabular, 11 inches thick, silty (coarse, well sorted, angular quartz), shell hash.
86. **Moderate brown (4YR 4/4) shale**, well consolidated, tabular, 3 inches thick, diatomaceous, black organic material, top of Carbonaceous Shale Facies, platy, leaf imprints.

87. **Light olive gray (5Y 5/2) clay**, glass particles, unknown cement, well consolidated, tabular, 17 inches thick, laterally extensive, wet on top, aquitard.
88. **Moderate brown (4YR 4/4) shale**, gypsum, unknown cement, well consolidated, tabular, 6 inches thick, diatomaceous, black organic material, leaf imprints.
89. **Dusky yellowish brown (10 YR 2/2) clay**, gypsum, unknown cement, moderately consolidated, tabular, 4 inches thick, friable, black organic material, silty (coarse, well sorted, subangular quartz).
90. **Light olive gray (5Y 5/2) clay**, gypsum, moderately consolidated, tabular, 24 inches thick, friable, silty (coarse, well sorted, subangular, quartz).
91. **Yellowish gray (5Y 7/2) clay**, very well consolidated, tabular, 19 inches thick, grades upward into siltstone.
92. **Moderate brown (5YR 4/4) shale**, gypsum, carnotite, unknown cement, well consolidated, tabular, 7 inches thick, abundant gypsum crystals and carnotite in top 2 inches.
93. **Dusky brown (5YR 2/2) volcanic ash**, well sorted, angular black glass, unknown cement, well consolidated, tabular, 7 inches thick, marker bed 3.2 m.y.
94. **Moderate brown (5YR 4/4) shale**, gypsum, unknown cement, well consolidated, tabular, 7 inches thick, diatomaceous, abundant black organic material top 2 inches, leaf imprints.
95. **Olive gray (5Y 3/2) coarse siltstone**, well sorted, subangular quartz, biotite, unknown cement, moderately consolidated, tabular, 28 inches thick.
96. **Moderate brown (5YR 4/4) shale**, gypsum, unknown cement, well consolidated, tabular, 6 inches thick, diatomaceous, 50% black organics, leaf imprints, elongated gypsum parallel to plates.
97. **Moderate yellowish brown (10YR 5/4) shale**, gypsum, unknown cement, well consolidated, tabular, 6 inches thick, diatomaceous, grass leaf imprints.
98. **Moderate brown (5YR 4/4) clay**, gypsum, cement, well consolidated, tabular, 8 inches thick.
99. **Moderate brown (5YR 4/4) very fine siltstone**, moderately sorted, subrounded clay, quartz, biotite, gypsum cement, well consolidated, tabular, 3 inches thick, 50% clay, some euhedral terminated quartz.
100. **Dusky yellow (5Y 6/4) medium siltstone**, well sorted, angular quartz, hematite, biotite, unknown cement, moderately consolidated, tabular, 6 inches thick, some euhedral quartz, 10% hematite.
101. **Dusky yellowish brown (10YR 2/2) coarse siltstone**, poorly sorted, subangular quartz, biotite, black lithic particles, unknown cement, poorly consolidated, tabular, 8 inches thick.
102. **Grayish brown (5YR 3/2) clay**, poorly consolidated, tabular, 3 inches thick, silty (moderately sorted, subangular quartz, biotite, black lithic particles).
103. **Moderate brown (5YR 3/4) fine sandstone**, moderately sorted, angular quartz, biotite, carnotite, calcite cement, moderately consolidated, tabular, 15 inches thick, laterally extensive, euhedral quartz and calcite, popcorn texture on surface.

- 104. Moderate yellowish brown (10YR 5/4) very fine sandstone**, well sorted, angular quartz, clay, feldspar, black lithic particles, gypsum, clay cement, moderately consolidated, tabular, 24 inches thick, clayey, laterally continuous for at least 100 feet.
- 105. Grayish red (10R 4/2) clay**, poorly consolidated, tabular, 9 inches thick, bottom of Carbonaceous Shale Facies, abundant black organic material, silty (very fine, angular quartz, black lithic particles, hematite).
- 106. Grayish orange (10YR 7/4) very fine siltstone**, well sorted, angular quartz, biotite, black lithic particles, hematite, calcite cement, moderately consolidated, tabular, 26 inches thick.
- 107. Very pale orange (10YR 8/2) coarse siltstone**, well sorted, angular quartz, sphene, calcite cement, poorly consolidated, tabular, 13 inches thick, friable.
- 108. Light olive gray (5Y 5/2) clay**, well consolidated, tabular, 14 inches thick, hematite, gypsum, silty (fine, well sorted, angular, quartz).
- 109. Olive black (5Y 2/1) clay**, well consolidated, tabular, 9 inches thick, gypsum, black organic material.
- 110. Olive gray (5Y 3/2) clay**, moderately consolidated, tabular, 17 inches thick, calcite nodules, friable, silty (medium, well sorted, angular quartz).
- 111. Yellowish gray (5Y 7/2) fine sandstone**, well sorted, angular quartz, biotite, apatite, calcite cement, very poorly consolidated, tabular, 8 inches thick, surface covered with calcite.
- 112. Very pale orange (10YR 8/2) fine sandstone**, well sorted, subangular quartz, biotite, sphene, calcite cement, very well consolidated, tabular, 7 inches thick.
- 113. Olive black (5Y 2/1) clay**, well consolidated, tabular, 16 inches thick, organic carbon.
- 114. Pale yellowish brown (10YR 6/2) very coarse siltstone**, well sorted, subangular quartz, biotite, feldspar, sphene, calcite cement, poorly consolidated, tabular, 12 inches thick.
- 115. Dark yellowish brown (10YR 4/2) very fine sandstone**, moderately sorted, subrounded quartz, biotite, sphene, calcite cement, poorly consolidated, tabular, 17 inches thick, frosted surfaces on quartz, calcite on surface.
- 116. Pale yellowish brown (10YR 6/2) very fine siltstone**, well sorted, subrounded quartz, biotite, sphene, calcite cement, moderately consolidated, tabular, 11 inches thick.
- 117. Olive black (5Y 2/1) clay**, well consolidated, tabular, 10 inches thick, friable, shell hash.
- 118. Grayish orange (10YR 7/4) coarse siltstone**, well sorted, subrounded quartz, no cement, very poorly consolidated, tabular, 5 inches thick.
- 119. Pale yellowish brown (10YR 6/2) medium siltstone**, poorly sorted, subangular quartz, biotite, muscovite, calcite cement, poorly consolidated, tabular, 15 inches thick, popcorn texture on surface.
- 120. Olive gray (5Y 3/2) coarse siltstone**, well sorted, subangular quartz, biotite, black lithic particles, no cement, poorly consolidated, tabular, 4 inches thick, fish scales.
- 121. Pale yellowish brown (10YR 6/2) clay**, moderately consolidated, tabular, 7 inches thick, calcite.

- 122. Moderate yellowish brown (10YR 5/4) very fine sandstone**, well sorted, subrounded quartz, black glass, calcite cement, poorly consolidated, tabular, 13 inches thick.
- 123. Pale yellowish brown (10YR 6/2) coarse sandstone**, gradational, subrounded quartz, lithic particles, gypsum, calcite cement, very poorly consolidated, channel, 62 inches thick, snail shell, calcite nodules, grades upward, fine sandstone at top, possible cross trough bedding.
- 124. Very pale orange (10YR 8/2) clay**, poorly consolidated, tabular, 5 inches thick, calcite, silty (coarse, well sorted angular quartz, biotite).
- 125. Pale yellowish brown (10YR 6/2) coarse siltstone**, well sorted, angular quartz, biotite, calcite cement, poorly consolidated, tabular, 22 inches thick.
- 126. Grayish orange (10YR 7/4) clay**, moderately consolidated, tabular, 8 inches thick, friable, silty (coarse, well sorted, subangular quartz).
- 127. Pale yellowish brown (10YR 6/2) coarse siltstone**, well sorted, angular quartz, biotite, no cement, very poorly consolidated, tabular, 28 inches thick, white calcite on surface.
- 128. Pale yellowish brown (10YR 6/2) clay**, well consolidated, tabular, 9 inches thick, silty (coarse, well sorted, angular quartz).
- 129. Olive black (5Y 2/1) clay**, moderately consolidated, tabular, 1 inches thick, calcite, silty (coarse, well sorted, quartz, granite lithic particles).
- 130. Dark yellowish brown (10YR 4/2) coarse siltstone**, well sorted, angular quartz, black lithic particles, biotite, muscovite, gypsum, calcite cement, poorly consolidated, tabular, 17 inches thick, surface covered by white evaporite.
- 131. Olive black (5Y 2/1) medium sandstone**, moderately sorted, subrounded quartz, clay, biotite, hematite, gypsum, clay cement, moderately consolidated, tabular, 10 inches thick, also found on top of bald knob.
- 132. Very pale orange (10YR 8/2) very coarse siltstone**, well sorted, subangular quartz, biotite, black lithic particles, hematite, calcite cement, poorly consolidated, tabular, 7 inches thick.
- 133. Pale yellowish brown (10YR 6/2) coarse siltstone**, well sorted, subangular quartz, biotite, calcite cement, moderately consolidated, tabular, 5 inches thick.
- 134. Pale yellowish brown (10YR 6/2) very fine sandstone**, well sorted, angular quartz, biotite, hematite, calcite cement, moderately consolidated, tabular, 27 inches thick.
- 135. Very pale orange (10YR 8/2) medium siltstone**, well sorted, angular quartz, biotite, calcite cement, moderately consolidated, tabular, 30 inches thick.
- 136. Grayish orange (10YR 7/4) coarse siltstone**, well sorted, angular quartz, biotite, calcite cement, moderately consolidated, tabular, 18 inches thick.
- 137. Dark yellowish brown (10YR 4/2) medium siltstone**, well sorted, subangular quartz, biotite, calcite cement, moderately consolidated, tabular, 22 inches thick, black organic material, shell hash.
- 138. Grayish orange (10YR 7/4) very coarse siltstone**, well sorted, subangular quartz, biotite, calcite cement, moderately consolidated, tabular, 9 inches thick.

- 139. Pale yellowish brown (10YR 6/2) very coarse siltstone**, well sorted, subangular quartz, biotite, calcite cement, moderately consolidated, tabular, 7 inches thick.
- 140. Grayish orange (10YR 7/4) fine sandstone**, moderately sorted, subrounded quartz, black lithic particles, biotite, hematite, calcite cement, poorly consolidated, tabular, 5 inches thick.
- 141. Pale yellowish brown (10YR 6/2) very coarse siltstone**, well sorted, subangular quartz, biotite, black lithic particles, gold, calcite cement, very poorly consolidated, tabular, 6 inches thick.
- 142. Grayish orange (10YR 7/4) coarse siltstone**, well sorted, angular quartz, biotite, hematite, calcite cement, moderately consolidated, tabular, 13 inches thick.
- 143. Dark gray (N3) volcanic ash**, well sorted, angular black lithic particles, no cement, well consolidated, tabular, 2 inches thick.
- 144. Pale yellowish brown (10YR 6/2) clay**, well consolidated, tabular, 6 inches thick, calcite, sandy (very fine, moderately sorted, subrounded quartz, biotite).
- 145. Dark yellowish brown (10YR 4/2) very fine sandstone**, moderately sorted, angular quartz, biotite, unknown cement, well consolidated, tabular, 8 inches thick.
- 146. Pale yellowish brown (10YR 6/2) very fine sandstone**, well sorted, angular quartz, biotite, calcite cement, poorly consolidated, tabular, 11 inches thick.
- 147. Dark yellowish brown (10YR 4/2) clay**, well consolidated, tabular, 21 inches thick.
- 148. Pale yellowish brown (10YR 6/2) coarse siltstone**, well sorted, subangular quartz, biotite, unknown cement, moderately consolidated, tabular, 8 inches thick.
- 149. Grayish orange (10YR 7/4) medium siltstone**, well sorted, angular quartz, hematite, calcite cement, moderately consolidated, tabular, 24 inches thick.
- 150. Pale yellowish brown (10YR 6/2) clay**, well consolidated, tabular, 5 inches thick, calcite, friable.
- 151. Dark yellowish brown (10YR 4/2) clay**, well consolidated, tabular, 6 inches thick, calcite, friable, black organic matter.
- 152. Dark yellowish brown (10YR 4/2) very fine sandstone**, well sorted, angular quartz, lithic particles, biotite, calcite cement, poorly consolidated, tabular, 3 inches thick, gradational with upper unit, bioturbated.
- 153. Pale yellowish brown (10YR 6/2) fine sandstone**, moderately sorted, rounded quartz, lithic particles, biotite, gypsum, calcite cement, very poorly consolidated, tabular, 9 inches thick, gradational with upper unit, bioturbated.
- 154. Moderate yellowish brown (10YR 5/4) very fine sandstone**, well sorted, subangular quartz, biotite, calcite cement, very poorly consolidated, tabular, 9 inches thick, gradational with upper unit, bioturbated.
- 155. Pale yellowish brown (10YR 6/2) very coarse siltstone**, well sorted, angular quartz, biotite, black lithic particles, calcite cement, very poorly consolidated, tabular, 5 inches thick.
- 156. Pale yellowish brown (10YR 6/2) clay**, well consolidated, tabular, 8 inches thick, gypsum, calcite, friable.

- 157. Dark yellowish brown (10YR 4/2) clay**, moderately consolidated, tabular, 4 inches thick, friable.
- 158. Dusky yellowish brown (10YR 2/2) clay**, poorly consolidated, tabular, 26 inches thick, 50% black organic material.
- 159. Dark yellowish brown (10YR 4/2) clay**, poorly consolidated, tabular, 4 inches thick, friable, unknown white particles.
- 160. Pale yellowish brown (10YR 6/2) very coarse siltstone**, well sorted, angular quartz, biotite, hematite, calcite cement, poorly consolidated, tabular, 19 inches thick.
- 161. Dark yellowish brown (10YR 4/2) clay**, poorly consolidated, tabular, 15 inches thick, silty (medium, well sorted, angular quartz), bioturbated.
- 162. Grayish orange (10YR 7/4) very coarse siltstone**, well sorted, angular quartz, biotite, hematite, calcite cement, well consolidated, tabular, 17 inches thick.
- 163. Moderate yellowish brown (10YR 5/4) fine sandstone**, moderately sorted, subangular quartz, biotite, hematite, calcite cement, very poorly consolidated, tabular, 21 inches thick.
- 164. Moderate yellowish brown (10YR 5/4) very fine sandstone**, well sorted, angular quartz, biotite, hematite, calcite cement, very poorly consolidated, tabular, 28 inches thick.
- 165. Dark yellowish brown (10YR 4/2) very fine sandstone**, moderately sorted, subrounded quartz, biotite, clay, hematite, calcite cement, poorly consolidated, tabular, 20 inches thick.
- 166. Grayish orange (10YR 7/4) very fine sandstone**, well sorted, subangular quartz, biotite, hematite, calcite cement, very poorly consolidated, tabular, 62 inches thick, bioturbated in lower portion.
- 167. Dark yellowish brown (10YR 4/2) medium siltstone**, well sorted, subangular quartz, biotite, hematite, calcite cement, poorly consolidated, tabular, 26 inches thick, friable.
- 168. Grayish orange (10YR 7/4) very fine sandstone**, moderately sorted, subrounded quartz, biotite, black lithic particles, calcite cement, moderately consolidated, tabular, 8 inches thick.
- 169. Moderate yellowish brown (10YR 5/4) fine sandstone**, moderately sorted, subangular quartz, biotite, lithic particles, calcite cement, poorly consolidated, channel, 96 inches thick, cross trough bedding (S-SE), snail shell, bottom of section covered by coluvium.

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